Integration and contagion:
Analysis of the consequences arising from interdependence in the financial sector

Inaugural-Dissertation
zur Erlangung des Grades Doctor oeconomiae publicae (Dr. oec. publ.)
an der Ludwig-Maximilians-Universität München

2012

vorgelegt von
Sebastian Missio

Referent:	Prof. Dr. Gerhard Illing
Korreferent:	Prof. Dr. Lutz Arnold
Promotionsabschlussberatung:	15. Mai 2013

Acknowledgements

During the process of writing this dissertation, I benefited from great support and manifold encouragement of various people. Before going into medias res of my thesis, this shall be appreciated first.

Most importantly, I would like to thank my supervisor Prof. Dr. Gerhard Illing for proficiently guiding me through the preparation of each single chapter of my dissertation. Frequent discussions on my thesis progress shaped my research agenda, encouraged me to continuously challenge and improve previous findings and fostered my ability to address diverse economic issues by thinking outside the box. I would like to extend my thanks to my second supervisor Prof. Dr. Lutz Arnold, who was always willing to comment on my progress and provided valuable advice on each topic. I am also grateful to Prof. Dr. Christoph Trebesch, who agreed to complete my thesis committee.

Besides my thesis committee, several other persons supported my research progress. Foremost, I am thankful for the fruitful cooperation with Dr. Sebastian Watzka, who coauthored the third chapter of this dissertation. Furthermore, gratitude is owed to my other colleagues of the Seminar for Macroeconomics, Dr. Desislava Andreeva, Sascha Bützer, Dr. Jin Cao, Dr. Moritz Hahn, Sebastian Jauch, Dr. Monique Newiak, Dr. Angelika Sachs, Thomas Siemsen, Michael Zabel and Dr. Jiarui Zhang for stimulating debates and to Agnès Bierprigl for her reliable administrative support. I am also indebted to fellow researchers at the Ludwig Maximilian University of Munich, the Bavarian Graduate Program in Economics and the Northwestern University, who actively participated in discussions on my thesis. Not to forget, I highly recognize and value the financial support from the Bavarian Graduate Program in Economics.

Finally, my deepest thanks go to my parents and loved ones for everlasting support and trust, not only during the process of writing this dissertation but during my whole life.

Sebastian Missio

Integration and contagion:
Analysis of the consequences arising from interdependence in the financial sector

List of figures

List of tables

List of acronyms

AR	Autoregressive
ARCH-LM	Autoregressive Conditional Heteroskedasticity – Lagrange Multiplier
BOFIT	Bank of Finland's Institute for Economies in Transition
CDS	Credit Default Swap
DCC	Dynamic Conditional Correlation
ECB	European Central Bank
EFSF	European Financial Stability Facility
EMI	European Monetary Institute
EMU	Economic and Monetary Union
ESM	European Stability Mechanism
EU	European Union
Fed	Federal Reserve
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GNP	Gross National Product

IMF	International Monetary Fund
MGARCH	Multivariate Generalized Autoregressive Conditional Heteroskedasticity
OLS	Ordinary Least Squares
PASOK	Panhellenic Socialist Movement
VAR	Vector Autoregression

Chapter 1

General introduction

1.1 Preface

This dissertation discusses advantages and disadvantages of interdependence in financial markets. With ongoing globalization, deregulation and technical progress, a more and more interconnected international financial system evolved over the course of time. This development towards greater interdependence opens up new opportunities, but at the same time creates substantial risks. The next three chapters of this dissertation hence analyze the consequences arising from interdependence in the financial sector.

This dissertation consists of three self-contained essays on financial market interdependences. In the second chapter, government bond market integration in the EMU is discussed as an example for the benefits emanating from increasing financial market interconnections. The third and the fourth chapter analyze contagion as an example for the drawbacks of stronger interdependences. The third chapter thereby concentrates on contagion on the country level and studies the development during the European debt crisis. The fourth chapter addresses the contagion topic on the company level.

The essays presented in Chapter 2 and Chapter 3 deal with empirical research questions. The essay presented in Chapter 4 is theoretical in nature. Introductory remarks – which shortly define the research topic and give an overview of the major results – are provided in the individual preface of each single chapter. A general outline of the next three chapters is described in the following.

1.2 Chapter outline

The next two chapters discuss advantages and disadvantages of financial market interdependence on the country level in the case of the EMU. In July 1990, the first stage of the unification process officially started. From then on, various measures meant to foster the economic and judicial convergence of the single member economies were introduced during the three stages of the EMU. Prominent and non-exhaustive examples comprise free movement of capital, joint monetary institutions like the ECB or its predecessor, the EMI, political agreements like the Stability and Growth Pact or last but not least the introduction of the euro as single currency at the beginning of the third and final stage in January 1999.

The way towards the EMU significantly influenced the bond markets of the single member states. Chapter 2 analyzes the European government bond market integration during the EMU process. The empirical analysis relies on the DCC model proposed by Engle (2002) and Engle and Sheppard (2001). Based on dynamic correlation estimates, the integration development of government bond markets is documented. In order to allow for regional comparisons, the study uses a sample comprised of euro area members from the core and the periphery and from EMU members which did not introduce the euro. In accordance with the literature, strong integration growth with regional differences is confirmed for all analyzed countries.

Besides these replicated results, Chapter 2 also provides further insights into the EMU process. The main contributions to the existing literature, which are, to the best of my knowledge, not yet analyzed in a comparable framework, address the timing of the integration upswings and the reasons for the integration. The analysis demonstrates that each of the three stages of the EMU fostered the bond market integration. Also, the beginnings of new EMU stages triggered individual integration waves. Consequently, not only the third stage of the EMU, which brought the euro in January 1999, but also the first stage starting in July 1990 and the second stage starting in January 1994 represent a break point in the European bond yield development in its own. Furthermore, the study sheds some light on the reasons of the bond market integration in Europe. By extending the DCC analysis to EU accession countries of May 2004 and to equity markets, it can be shown that especially the elimination of exchange rate risk is of major importance for the government bond market integration.

Fundamental convergence and an ex ante expectation of a bailout for euro area members also matter, but seemingly to a lesser extent.

The analysis of Chapter 2 comprises a time frame which starts in January 1987, three and a half years before the EMU process was initiated, and ends in December 2003, four years after the conclusion of the EMU process. At that end date, the government bond market integration seemed to be almost completed. Due to the integration development, arguably most member states of the EMU benefited a great deal from the stronger developing interdependences of the earlier more separated markets for sovereign debt. Since the beginning of the EMU, government bond yields converged and decreased steadily. Financing budgetary deficits both became easier and cheaper. Bond yield movements started to depend less on country specific information, but more heavily reacted to EMU wide developments. In total, member states of the EMU had to worry less about the government bond markets, as compared to the time before the integration process started. Also in the subsequent years after 2003, EMU members persistently profited from the interdependences within the government bond markets.

However, things started to change with the outbreak of the financial crisis in 2007 and a fortiori with the following European debt crisis since the end of 2009. From then on, some member states of the euro area faced the second sight of strong bond market interdependence, in that contagion. Greece was the first country within the euro area to suffer from dramatic refinancing problems. Following Greece, other member states such as Ireland, Portugal, Italy and Spain, found themselves trapped in a downward spiral of increasing government bond yields and deteriorating refinancing conditions.

The fate of the euro area countries, which have gotten into similar troubles as Greece, may be solely caused by own fundamental weaknesses, or else may be aggravated by contagion. Greece, the origin of the crisis, so to speak, may have infected the euro area with its own disease. This contagion question is addressed in Chapter 3. The study is joint work with Dr. Sebastian Watzka. The empirical approach applies the DCC methodology in combination with principal component analysis and comprises a time span ranging from January 2009 until December 2011. The examined country sample allows for a comparison of the results for the core and the periphery of the euro area. The study provides evidence for the existence of contagion to which especially the financially less solid periphery countries seem to be vulnerable to.

Interconnections with the Greek financial markets led to a negative spillover of the market turbulences to other euro area economies. By implementing rating data announcements into our analysis, we show that contagion is not only driven by fundamental country interdependences, but also by non-fundamentally justified reasons. The ailing financial system of Greece can trigger a higher default risk of banks and similar institutions in other countries, thereby creating a fundamentally justified threat for the financial stability abroad. Additionally, the joint integration process of the euro area can generate the notion that problems witnessed for one European economy may also be true for another one. Thus, bad news on Greece can trigger a non-fundamental extrapolation of that information to other countries. Both in the case of fundamentally justified and non-fundamental spillover, refinancing problems spread within the euro area. With higher integration of government bond markets, this contagion threat becomes more likely. The advantage of financial market interdependence thus can quickly turn into a disadvantage.

Besides the politically relevant conclusion of the existence of contagion during the European debt crisis, our main contribution to this frequently discussed topic is the applied methodology. In order to identify contagion, we combine principal component analysis with DCC modeling. While both methods have been used individually in contagion analyses, to the best of our knowledge, a combination of both has not been used yet. The same applies for our rating based analysis. Studying the effects of rating announcements on bond yields is not new to the literature. An approach, however, in which the connection of bond yield correlations and rating data is evaluated in order to distinguish between fundamentally and non-fundamentally justified contagion, is not known to us.

Finally, the contagion issue is not restricted to the country level. Interdependences between companies can also lead to spreading financial problems. This general fact recently gained huge attention again during the financial crisis starting in 2007. Contagion for the company level is discussed in Chapter 4. After the two empirical studies in Chapters 2 and 3, the company level analysis of the last chapter is theoretical in nature. It demonstrates that contagion between financial service providers can emanate from debt contracts, which are used, once market frictions render risk insuring state contingent contracts impossible. It is shown that such a contractual agreement generally protects the interest of the creditor adequately. In a severe crisis, however, the debt contract cannot prevent the spillover of financial distress from the debtor to the capital provider.

The contagion analysis of Chapter 4 is highly distinct from Chapter 3. On the one hand, the approach is theoretical in nature. On the other hand, also the concept of contagion is slightly different. In the third chapter, fundamentally and non-fundamentally driven contagion is analyzed. In the fourth chapter, only the fundamental connection between financial institutions is considered. Due to contractual linkages, illiquidity and insolvency problems can spread from one financial service provider to another. One company gets into a predicament, because the counterpart of the business contract defaults on its liabilities. The interdependence within the financial system once again proves to be problematic.

In the last chapter, a new model is built in order to capture interconnections within the financial system, which can lead to contagion on the company level. This model contributes to the literature, as it combines and modifies ideas from the existing literature in a way, such that contagious crises are represented as an unlikely but nevertheless possible event. Market participants are able to write contracts which prevent from negative spillovers in normal times, but which fail in highly rare extreme shock scenarios. In those dramatic cases, financial institutions are not able to manage the contagion threat alone. Yet, the study additionally provides measures, how governments can mitigate the arising problems by proper regulation and intervention.

This dissertation analyzes the consequences arising from interdependence in the financial sector. The proceeding coalescence of financial markets brings both advantages and disadvantages. Recognizing the benefits is crucial in order to evaluate measures fostering further interdependence. Identifying the drawbacks is important in order to understand the nature of a problem. Only with that knowledge, an effective treatment of the current issue or a suitable prophylaxis is possible.

Chapter 2

Government bond market integration and the EMU: Correlation based evidence

2.1 Preface: Integration

The concept of financial market integration is defined according to the law of one price: If two assets have an identical risk and return structure, both should have the same price. If financial markets are integrated, then the law of one price should be fulfilled.

In July 1990, the project of the EMU started and finally led to the introduction of the euro in January 1999. This process laid the foundation for government bond market integration in Europe. On 17.04.1989, the so-called Delors Report was published. In this report, the Committee for the Study of Economic and Monetary Union, presided by at that time President of the Commission of the European Communities Jacques Delors, proposed that economic and monetary union should be achieved in three stages:

"At its meeting on 27 and 28 June 1988 the European Council confirmed the objective of economic and monetary union for the Community. In accordance with its mandate, the Committee has focused its attention on the task of studying and proposing concrete stages leading towards the progressive realization of economic and monetary union. In investigating how to achieve economic and monetary union the Committee has examined the conditions under which such a union could be viable and successful. The Committee feels that concrete proposals towards attaining this objective can only be made if there is a clear understanding of the implications and requirements of economic and monetary union and if due account is taken of past experience with and developments in economic and monetary integration in the Community. Hence, Chapter II of this Report examines the principal features and implications of an economic and monetary union. Chapter III then presents a pragmatic step-by-step approach which could lead in three stages to the final objective. The question of when these stages should be implemented is a matter for political decision." (Delors Report, 1989, p. 12)

Chapter 2 of this dissertation analyzes the development of the government bond market integration during these three stages of the EMU. With the beginning of the EMU, government bond yields of member countries started to converge dramatically. According to the law of one price, yields converge once financial markets perceive that the country specific risks of the single EMU members converge.

Given this clearly observed yield convergence, there is an even stronger measure for bond market integration: If country specific risk factors converge and become seemingly identical, the single country's yield development is less dependent on idiosyncratic country factors. Instead it is more and more dependent on a common European factor, which drives all bond markets simultaneously. As a consequence, bond markets tend to move in parallel. This bond yield harmonization leads to increased bond yield correlations between the EMU countries. Therefore, these correlations are analyzed in order to evaluate the bond market integration during the process of the EMU.

Based on the results from DCC models, this study shows that the European bond market integration was highly advanced, but that the degree of integration differed between the single EMU countries. It is confirmed statistically that the first, the second and the third stage of the EMU each contributed as a whole to the integration process and that each beginning of a new stage triggered an own wave of government bond market integration progress.

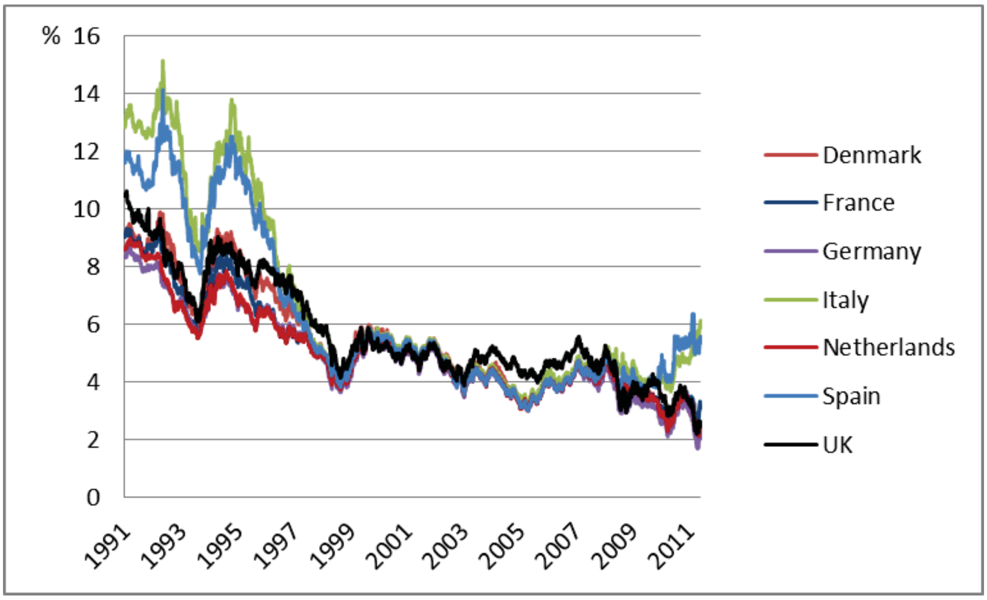
European bond market integration was possible, because country specific risks of the EMU members seemingly converged. The last part of Chapter 2 sheds light on the reasons for this risk convergence and thus the integration development. The DCC analysis is expanded to the EU accession in 2004, to the euro introduction in Slovakia in 2009 and to the equity markets during the process of the EMU. No strong conclusions can be drawn, yet estimation results indicate that the elimination of the exchange rate risk is of major importance for the bond market integration. Fundamental integration and a potential ex ante expectation that countries of the euro area will be bailed out once there is financial distress are of minor importance.

2.2 Introduction

The EMU represents a supranational construction, which used to have beneficial effects on the financial stance of its members. The history of the EMU is characterized by years of strong government bond yield convergence, which rendered the debt servicing less costly. This development, however, came to an abrupt ending with the start of the European debt crisis and the resulting strong increase of interest rates on sovereign debt of some member countries.

For seven member countries, an overview of the history of the bond yield development since the early EMU is provided in Figure 2.1.[1] During the 1990's the bond yields generally started to decline and to converge. With the 2000's, this convergence process was almost completed and bond yields remained converged for the subsequent years. This was only interrupted by the outbreak of the European debt crisis in late 2009.

Figure 2.1: Government bond yield development



Percentage 10-year benchmark government bond yields for seven EMU founding members, Denmark, France, Germany, Italy, the Netherlands, Spain and the UK.

The intra-EMU yield convergence is referred to several causes. A non-exhaustive literature list includes Blanco (2002), who stresses the disappearing exchange rate risk, Pagano and von

[1] As long as not indicated differently, all data used throughout the dissertation is provided on Datastream.

Thadden (2004), who address liquidity and the reduced segmentation of the institutional framework for governmental bonds, or Côté and Graham (2004), who account for the shared fiscal standards and monetary cooperation.

In comparison to examining convergence, this study analyzes if also a synchronization of bond yield movements can be identified. Bond yield convergence means that spreads between single government bonds decreased in mean, but it says nothing about the exact timing and the exact magnitude of yield movements. Given the undisputed yield convergence within the EMU, identification of a higher parallelism of yield movements provides even stronger evidence for bond market integration.

If there is synchronization of the timing, the direction and the degree of yield movements, not only a high degree of bond yield convergence, but also a significant increase in correlations between sovereign debt yields should be observed. Therefore, this paper applies the DCC model proposed by Engle (2002) and Engle and Sheppard (2001), in order to evaluate the development of yield correlation estimates.[2]

Based on estimated time series of correlation coefficients between bond yields of EMU countries, the integration process is documented. The DCC methodology is considered highly suitable for an analysis of financial market integration. The dynamic nature of the correlation estimates allows for a detailed observation of the chronological development of the integration process. Additionally, heteroskedasticity adjustment guarantees that changes in the level of correlations are not solely driven by changes in volatility.

The study clearly shows that bond market integration is fostered by the monetary unification process. No equally strong conclusion regarding the reasons for this development can be drawn. Yet, the elimination of exchange rate risk seems to be of major importance, while fundamental integration and an expectation of a bailout provision for euro area members play a less crucial role.

[2] For an explanation of the DCC model refer to Appendix A in Subsection 2.8.1.

Chapter 2 is structured as follows: Subsection 2.3 reviews the literature and presents the contribution to it. Subsection 2.4 shows the development towards stronger EMU bond market integration and regional characteristics. In Subsection 2.5, the relevance of the three stages of the EMU for the integration process is elaborated. Subsection 2.6 evaluates potential reasons for the bond market integration. The study is therefore extended to cover Eastern European EU accession countries and equity markets. Subsection 2.7 concludes.

2.3 Literature

Applying correlations as measure of market integration is not new to the literature. Once markets become more dependent on each other, also a connection of the market risks emerges. Bertero and Mayer (1990) investigate interdependences between markets by static correlation coefficients. According to Forbes and Rigobon (2002), a persistently high level of correlations between two countries' financial assets implies strong interdependence as economic interconnections lead to strong co-movement of assets.

Cappiello et al. (2006a) provide evidence that correlation based measures of bond market integration are highly adequate. Arguing that after a successful integration process, yield movements should be more attributable to global factors as compared to idiosyncratic factors, the authors develop a factor model which distinguishes between common and local drivers of financial assets. The observation of an increase in correlations signifies that the financial markets start to pay more attention on information which concerns the integrated area as a whole. Country specific events, which affect the yields idiosyncratically and therefore lead to less correlation, are less relied upon.

The integration process of the EMU has been analyzed with measures of bond yield co-movements as indicators of a gain in importance of aggregated European shocks over local country specific factors. Baele et al. (2004) investigate to which extent bond yield movements can be attributed to the movement of the German 10-year benchmark government bond yield, which is assumed to proxy EMU wide shocks. The remaining bond fluctuation is referred to regional information. It is found that during the European integration process idiosyncratic shocks became significantly less important for yield movements as compared to high explanatory power of common factors.

In order to analyze the bond market integration during the European integration process, Ehrmann et al. (2011) use unconditional static correlations and additionally a factorization of global and regional information. Strong integration is identified, which is primarily referred to the common monetary policy and the elimination of exchange rate risk. Abad et al. (2010) refer to a CAPM based analysis and also provide evidence that since the adoption of the single currency, intra-EMU information became the more important bond yield driver, as compared to either global or local effects.

Finally, Cappiello et al. (2006b) also apply the DCC methodology and examine the integration process of the EMU. Using weekly data of euro area and non-euro area countries, correlation time series are estimated and integration within the EMU is confirmed.

All aforementioned papers addressing the EMU are providing results in favor of a strong bond market integration process in Europe. In this study, all major results are replicated, statistically confirmed and enhanced, however completely based on the results of the DCC methodology.

Firstly, this study agrees on earlier results that the integration process within the EMU was highly advanced and that the degree of integration differed between the single member countries. Secondly, it is confirmed statistically that the first, the second and the third stage of the EMU contributed significantly to the integration process. Additionally, a test procedure investigating the exact timing of significant and permanent upswings of bond market integration is developed.

Earlier studies on the EMU found either the exact date of monetary unification in 1999 or some earlier date, from which on the subsequent unification could be realistically expected, as single break point in the European bond yield development. This analysis reveals that besides the euro introduction in 1999, in fact also the beginning of the monetary unification process in 1990 and the beginning of the second stage of the monetary unification process in 1994 each triggered a new wave of integration. The European bond yield development thus shows three distinct break points each fostering the integration process itself.

Thirdly, the study tries to shed some light on the particular reason for the bond market integration in Europe. In general, due to the law of one price, bond yield convergence and a synchronization of bond yield movements occur, if financial market participants perceive a convergence of the single countries' risk factors. This perceived convergence of country specific risk within the euro area can be caused by distinct aspects: First, the elimination of exchange rate risk prevents currency fluctuations. Second, there is integration in fundamental values, as countries of the euro area become more similar because of economic and judicial prerequisites for EMU membership. Third, there is an ex ante expectation in a potential bailout provision. Financial markets anticipate that countries will be saved from severe financial distress, once they belong to the euro area. Country specific risk is then distributed among all euro area countries.

This list of potential reasons for risk convergence is by no means complete. Yet, an evaluation of the importance of the three mentioned aspects is considered. The DCC analysis is therefore extended to the bond markets of EU accession countries and to equity markets of the EMU founding members. No strong conclusions can be drawn from this exercise, but there is some evidence that the exchange rate elimination is a major contributor to the bond market integration. The other two factors are not dismissed as cause for risk convergence, but they seem to be of minor importance.

2.4 EMU bond market integration

In July 1990 the first stage of the EMU was launched. From January 1994 until December 1998, the second stage of the EMU served as preparation for the final monetary unification. The introduction of the euro in January 1999 marked the beginning of the third and final stage of the EMU.

In this section, the DCC based correlation analysis is carried out for seven countries which participated in the foundation of the EMU. Subsection 2.4.1 describes the data used in the model. Subsection 2.4.2 analyzes the dynamic correlation development and its implications for the integration success.

2.4.1 Yield data

In order to investigate the harmonization of bond yield movements since the implementation of the EMU, week daily 10-year benchmark government bond yields for a sample of seven countries, Denmark, France, Germany, Italy, the Netherlands, Spain and the UK are used. The benchmark yield represents that yield which countries need to offer for newly emitted 10-year government bonds in order to attract investors.

The analysis spans a time period ranging from January 1987 until December 2003 for Denmark, France, Germany and the UK and from January 1992 until December 2003 for Italy and Spain. A lack of data availability renders it impossible that also the calculations for the latter two countries completely comprise all three stages of the EMU. After four years of the third stage of the EMU, the time span stops by the end of 2003. The surge in bond yield correlations is almost completed by then and the integration level remains comparably high in the subsequent years until the start of the financial crisis in late 2009. Prolonging the time period until the financial crisis would only further aggravate all results regarding the third stage of the EMU. An analysis of the disintegration process since the start of the financial crisis is not considered in Chapter 2 but in Chapter 3 of this dissertation.

The restriction to the seven countries is chosen according to data availability and in order to support intra-EMU comparisons of different country groups. Germany is the biggest and arguably most solid economy within the EMU. In the following, a DCC system is estimated for seven EMU founding members. Each country's dynamic bond yield correlations are calculated against the German bond yields. Rising correlations indicate a stronger integration of the other six government bond markets with the German government bond market.

With France and the Netherlands, two countries highly equivalent to Germany are analyzed. Both Northern European economies are financially similarly solid. Major problems remained absent even in the wake of the European debt crisis. Denmark and the UK also represent two financially solid EMU founding members, which, however, did not participate in the third stage of the EMU. Therefore, the two countries are confined to the others for political reasons regarding the unification process. Finally, Italy and Spain are members of the distressed Southern European country block. Since late 2009, the two countries are massively attacked by the financial markets and suffer from strongly increasing borrowing costs. While also participating in the euro area, Italy and Spain are far more distinct from Germany as compared to France and the Netherlands.

Bond market integration is measured by increases in bond yield correlations. Within this study, it is of special interest how the EMU process fostered the bond market integration in Europe. Yet, also the progressively developing globalization can cause stronger bond market integration in Europe, independently from the EMU process. Therefore, a second DCC system is estimated for the United States and Germany. Dynamic conditional correlations between these two countries' bond yields can be seen as a proxy for the bond market integration caused by globalization in general.

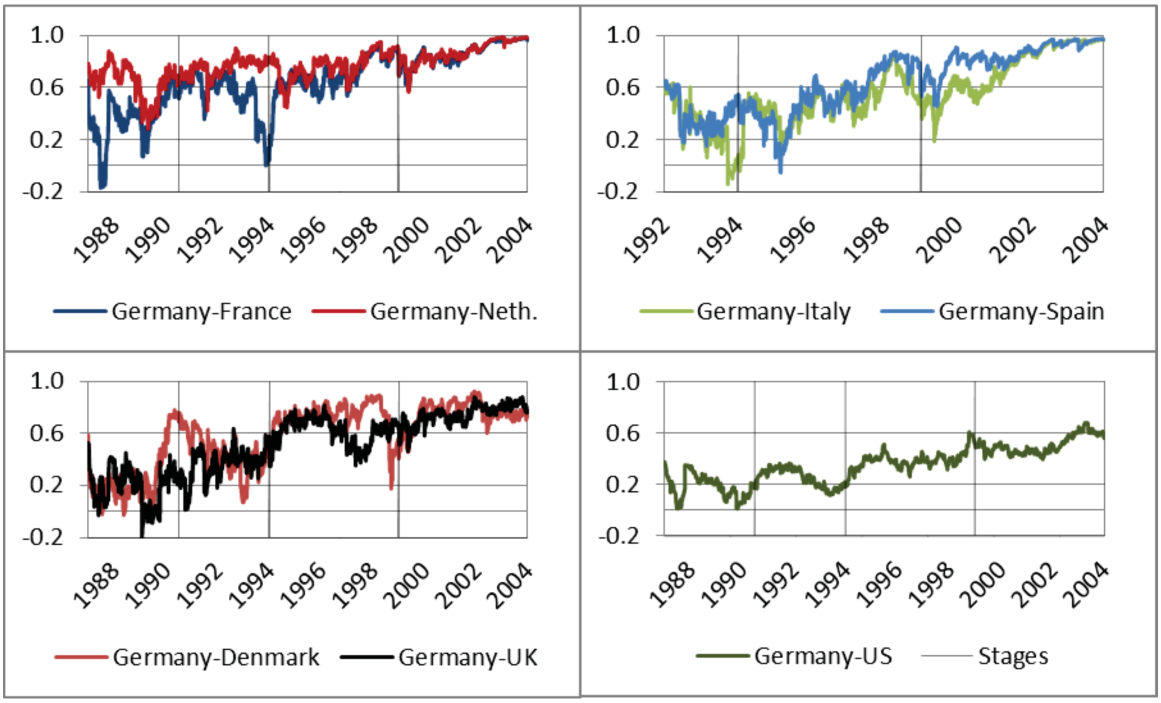
2.4.2 Correlation development

The estimated correlation dynamics are used to analyze the degree of the EMU integration process. If the EMU countries become more integrated, European information gains in importance as driver of bond yield movements as compared to country specific information. A stronger parallelism of bond yield developments is therefore acknowledged as evidence for stronger bond market integration. An increase in parallelism between the German government bond yields with the other six countries comes along with an increase of correlation coefficients between the respective bond yields over time.

Figure 2.2 shows the development of the correlations with the German benchmark government bond yields. The time-varying lines depict the estimated dynamic conditional correlation series. The vertical lines indicate the beginning of the stages of the EMU process in July 1990, January 1994 and January 1999. Table 2.1 summarizes the graphical results descriptively. Average correlations pre stage one and within each of the three stages of the EMU are provided. Additionally, the percentage stage to stage growth rates of average correlations and the percentage two stage growth rates are displayed.[3]

[3] For the DCC model specification of the EMU bond market analysis refer to Table B.2.1 of Appendix B in Subsection 2.8.2.

Figure 2.2: Integration analysis of EMU bond markets



Dynamic conditional correlation estimates of 10-year benchmark government bond yields between Germany vis-à-vis France and the Netherlands (upper left subplot), Denmark and the UK (lower left subplot), Italy and Spain (upper right subplot) and the US (lower right subplot). The upper left, lower left and lower right subplot cover a time frame ranging from January 1987 until December 2003. The upper right subplot covers a time frame ranging from January 1992 until December 2003, as the yield series for Italy and Spain only begin in 1992. Vertical lines indicate the stages of the EMU.

The graphical inspection leads to three initial results all in line with the literature. First, for all country groups, a strong tendency for rising bond yield correlations can be recognized. This result is not only true for the EMU countries, but also applies for the US. The bond yield correlation between Germany and the US, however, clearly falls short as compared to the EMU countries. With each new stage of the EMU, the difference between average correlations of the US and of the European countries gets in almost all cases larger and larger. This development draws the clear conclusion that the EMU process contributed to the European bond market integration. Globalization plays an important role, but the EMU even further fostered stronger bond market integration of all six European countries with Germany.

A second insight from the visual inspection is the regional differentiation between the different members of the EMU. The average correlations of the Northern European countries' bond yields vis-à-vis the German bond yields are the highest within the sample. France and the Netherlands display the strongest integration with the German government bond market. The Southern European economies start from the lowest average correlations in the early 1990's, but the subsequent development describes an immense catch up process. Only a few years after the introduction of the euro, Italy and Spain reach highly identical integration degrees as Northern Europe. Interestingly, this last aspect is not true for Denmark and the UK. While rising correlations also favor stronger integration with German bond markets, the average correlations of the two non-euro area countries after the introduction of the single currency in January 1999 fall short as compared to the euro area.

Table 2.1: Descriptive statistics of EMU correlation estimates

Correlation series		Pre stage 1	Stage 1	Stage 2	Stage 3
Germany-France	Ø-correlation	0.365	0.547	0.690	0.865
	Stage %-growth		50%	26%	25%
	2-Stage %-growth			89%	58%
Germany-Netherlands	Ø-correlation	0.642	0.754	0.767	0.875
	Stage %-growth		17%	2%	14%
	2-Stage %-growth			19%	16%
Germany-Denmark	Ø-correlation	0.263	0.444	0.726	0.760
	Stage %-growth		69%	64%	5%
	2-Stage %-growth			176%	71%
Germany-UK	Ø-correlation	0.193	0.363	0.616	0.746
	Stage %-growth		89%	70%	21%
	2-Stage %-growth			220%	105%
Germany-Italy	Ø-correlation		0.298	0.483	0.746
	Stage %-growth			62%	54%
	2-Stage %-growth				150%
Germany-Spain	Ø-correlation		0.388	0.537	0.844
	Stage %-growth			38%	57%
	2-Stage %-growth				118%
Germany-US	Ø-correlation	0.182	0.253	0.387	0.510
	Stage %-growth		39%	53%	32%
	2-Stage %-growth			112%	102%

For each correlation series, the first row shows the average correlation estimates of the French, Dutch, Danish, British, Italian, Spanish and US vis-à-vis the German 10-year benchmark government bond yields before the first stage and within the three stages of the EMU. The second row shows the percentage growth of average correlations from stage to stage and the third row shows the percentage correlation growth from pre stage one to stage two and from stage one to stage three. For Italy and Spain, statistics referring to pre stage one data are missing as the time series only begin in 1992.

Third, the euro area countries reach almost perfect bond market integration with correlation estimates close but short to one. Reasons for the failure of perfectly complete bond market integration are diverse. Arguments contain differences in country specific credit risk (Codogno et al., 2003; Schuknecht et al., 2009), differences in liquidity risk (Adjaouté and Danthine, 2003; Favero et al., 2010; Gomez-Puig, 2006; Jankowitsch et al., 2006), or a combination thereof (Bernoth et al., 2012; Manganelli and Wolswijk, 2009).

2.5 The role of the EMU stages for bond market integration

The graphical analysis showed a general trend towards higher integration of the EMU bond markets. Now the role of the single stages of the monetary unification process for the bond market integration is evaluated. Subsection 2.5.1 measures that in each stage the average integration level increases in general. In Subsection 2.5.2 it is shown that specifically the beginning of each stage triggers a separate wave of integration and thus marks an own break point in the bond yield development.

2.5.1 EMU stages contribute to bond market integration

In order to analyze if bond market integration significantly increases in the different stages of the EMU, the following dummy regression is proposed. The estimated correlation series from the DCC model, i.e. the dynamic conditional correlations between the German vis-à-vis the other six EMU countries' government bond yields, are applied to an AR(1) model. The dynamic conditional correlations are regressed on dummy parameters representing the single stages of the EMU as well as on a lag of the conditional correlations, in order to remove any remaining autocorrelation in the residuals. The regression equation is provided in (2.1).

$$\rho_t = \varphi + \kappa\rho_{t-1} + \eta D_{1,t} + \mu D_{2,t} + \omega D_{3,t} + u_t \qquad (2.1)$$

The autoregressive parameters ρ_t are the dynamic conditional correlation estimates, $D_{1,t}$, $D_{2,t}$ and $D_{3,t}$ represent stage dummies, φ, κ, η, μ and ω the parameters to be estimated and u_t the error term.

The composition of the dummy variables depends on the specific stage to be tested. Exemplarily, in order to test whether the first stage of the EMU significantly contributes to the bond market integration, the time span before the first stage is taken as base scenario and no dummy for that time period is included into equation (2.1). Accordingly, the first dummy variable $D_{1,t}$ then represents the first stage of the EMU and takes a value of one between 01.07.1990 and 31.12.1993 and zero otherwise. The second dummy variable $D_{2,t}$ represents the second stage and takes a value of one between 01.01.1994 and 31.12.1998. The dummy representing the third stage, $D_{3,t}$, takes a value of one between 01.01.1999 and the end of the sample on 31.12.2003.

As long as the bond market integration advances significantly during the first stage of the EMU, the parameter of $D_{1,t}$ must be significantly positive. If the parameter is significantly positive, there is statistical evidence that the average correlation level increases during stage one as compared to the time pre stage one, i.e. the base period.

The test procedure for the impact of the other two stages on the bond market integration is similar. In order to evaluate if yield correlations significantly increase during stage two as compared to stage one, the first stage needs to be used as base scenario and is not included as dummy in equation (2.1). The three dummy variables capture the time periods pre stage one, stage two and stage three. If now the coefficient of $D_{2,t}$ is significantly positive, the level of bond market integration during stage two on average surpasses the level during stage one. For testing stage three of the EMU, the second stage is the base scenario and the coefficient of $D_{3,t}$ needs to be evaluated.

As there are three stages of the EMU, three distinct versions of equation (2.1) are calculated for the German vis-à-vis the French, Dutch, Danish and British bond yield correlations. In the first version, the time period pre stage one represents the base scenario and the coefficient of $D_{1,t}$ is tested, in the second version the time during the first stage represents the base scenario and the coefficient of $D_{2,t}$ is tested and in the third version the time during the second stage represents the base scenario and the coefficient of $D_{3,t}$ is tested. As the yield series of Italy and Spain start in 1992, the dummy parameters in equation (2.1) need to be reduced to two and only the second and the third version of equation (2.1) can be estimated. Table 2.2 shows those coefficient estimates which are relevant for evaluating the contribution of the single stages of the EMU to the bond market integration.[4]

Table 2.2: EMU stage dummy regression estimates

Correlation series	Stage 1	Stage 2	Stage 3
Germany-France	0.004***	0.004***	0.003*
	(3.517)	*(4.269)*	*(1.894)*
Germany-Netherlands	0.003	0.000	0.003***
	(0.283)	*(0.202)*	*(7.370)*
Germany-Denmark	0.004	0.007***	0.001***
	(1.440)	*(13.146)*	*(3.957)*
Germany-UK	0.010***	0.014	0.007***
	(4.566)	*(0.348)*	*(14.218)*
Germany-Italy		0.005***	0.005***
		(3.486)	*(5.100)*
Germany-Spain		0.003**	0.006***
		(2.315)	*(21.890)*

Dummy parameter estimates testing the contribution of the single stages of the EMU to the bond market integration from equation (2.1) are shown for dynamic conditional correlation series of French, Dutch, Danish, British, Italian and Spanish 10-year benchmark government bond yields vis-à-vis German 10-year benchmark government bond yields. As the time series for Italy and Spain only begin in 1992, equation (2.1) is estimated with only two dummy variables and the column referring to stage one remains blank. Significantly positive coefficients indicate that average bond market integration between Germany and the respective counterpart increases as compared to the respective stage before. Upper numbers refer to the coefficient estimates. *, ** and * denote rejection of H0 (the parameter being equal to zero) and statistical significance at the 10%, 5% and 1% confidence level, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses.**

For all countries in the sample, the statistical analysis confirms that one stage, two stages, or even all three stages of the EMU significantly foster the bond market integration with Germany. For the French-German correlations, the first stage dummy coefficient takes a value of 0.004 and is highly significantly positive. Thus, the average correlation increases during the first stage of the EMU as compared to the period pre first stage. With a value of again 0.004, also the second stage dummy is significantly positive and the average correlation

[4] For each of the 12 EMU stage dummy regressions for France, the Netherlands, Denmark and the UK, one intercept, one autoregressive parameter coefficient and three dummy coefficients are estimated. For the four EMU stage dummy regressions for Italy and Spain, the amount of dummy coefficients is reduced to two. As explained, however, only one of the dummy coefficients in each regression can be interpreted with regard to the question of contribution to the bond market integration. Because of clarity and space reasons, Table 2.2 only shows these interpretable coefficient estimates.

during the second stage increases as compared to the first stage. Finally, with a significant coefficient of 0.003, the average correlation again increases during the third stage as compared to the second stage. During each new stage of the EMU, the French and the German government bond markets become more integrated as compared to the respective stage before.

A significant contribution of all three stages to the bond market integration with Germany is not confirmed for the other countries. A significantly positive effect of the first stage, however, also applies to the UK. During the second stage, average correlations also increase for Denmark, Italy and Spain. Interestingly, the third stage fosters bond market integration for all six countries, even for the two countries not participating in the euro area. According to Figure 2.2, the integration process for Denmark and the UK slows down after the beginning of the third stage. The statistical confirmation might be explained with globalization in general, or because it took some time to implement all fundamental harmonization required by the two stages in which Denmark and the UK participated. Thus, integration starts from a lower level in the beginning of stage two and therefore decreases the average correlation during stage two.

2.5.2 Beginnings of EMU stages trigger bond market integration

The single stages of the EMU each introduce economic and judicial standards, which affect the seven analyzed countries in a similar way. It is therefore reasonable that the bond market integration advances during each single stage. This subsection now evaluates which specific moments in the history of the EMU initiate this integration growth. Identifying particular years which trigger the integration process is more complicated than finding that average correlations increase during a whole stage of the EMU. A convention of what is meant by a trigger needs to be agreed on initially.

A year in which average correlations increase significantly after one or more years of stable or decreasing correlations can be seen as a trigger for bond market integration. However, as observed in Figure 2.2, the dynamic correlations of the different country pairs are erratic. Upswings and downswings take turn regularly. Consequently, it is not conducive to identify an integration trigger each time the correlations increase for a short time span. A long term increase of average correlations changes the situation. If an upswing is more permanent, a sustainable integration trigger can be identified. Not only the current year then shows a significant increase of average correlations, but this increase is kept or even augmented during the next years.

Each year in which a sustainable growth of bond yield correlations is initiated, is called an integration trigger. A trigger year launches a long term period of bond market integration. This integration period lasts as long as the average correlations grow further or remain at a once reached increased level. Once, however, average correlations significantly drop below an already reached level, the initiated integration wave comes to an end. If such a disintegration phase interrupts the correlation growth, the integration process needs to be revived again.

In order to identify the years which trigger the integration process, a test procedure similar to equation (2.1) is proposed. The estimated correlation series from the DCC model are again applied in an AR(1) model and regressed on a set of dummy parameters. These dummy parameters now represent each single year of the analyzed time frame of this study. The estimation equation is provided in (2.2).

$$\rho_t = \varsigma + \lambda \rho_{t-1} + \sum_{i=1}^{16} \theta_i \, D_{i,t} + u_t \tag{2.2}$$

Again, ρ_t represents the estimated dynamic conditional correlations, $D_{i,t}$ the dummy variables, ς, λ and θ_i the parameters to be estimated and u_t the error term. In equation (2.2), the dummy variables are not representing the stages of the EMU but each year between 1987 and 2003. The composition of the dummy variables depends on the specific year to be tested. If it is tested whether the year 1988 triggered a permanent surge in correlations, the year 1987 represents the base and has no dummy in equation (2.2). The 16 years from 1988 until 2003 are captured by 16 dummy variables, which take a value of one during their respective year and a value of zero otherwise.

To investigate whether 1988 triggers permanent bond market integration, several steps are required. If the year 1988 initiates long term correlation growth, the parameter coefficient of $D_{1,t}$ must be significantly positive. Only then, the average correlations significantly increase in 1988 as compared to the base year 1987. However, a significantly positive coefficient of $D_{1,t}$ only confirms that correlations increase in the year 1988. So far, nothing can be said about the sustainability of that integration upswing. Therefore, also the coefficient of $D_{2,t}$ is tested for positive significance in the next step. If that is the case, then also in 1989 the average correlations are on a higher average level than in the base year 1987. An immediate reverse of the integration process can thus be rejected. Subsequently, the year 1990 is compared to the base year 1987. The same procedure continues as long as the average correlations remain on a level significantly higher as compared to the base year 1987. Thereby, the length of the integration period starting in 1988 can be revealed.

Subsequently, the same test procedure is systematically applied for all base years between 1987 and 2000. Exemplarily, in order to test, if the year 1989 serves as a trigger year, the base year switches from 1987 to 1988 and the 16 dummy variables account for the year 1987 and the 15 years from 1989 to 2003. The dummy coefficient of the year 1989 is tested for positive significance. If the average correlations in 1989 are significantly higher than in the base year 1988, the dummy coefficient of the year 1990 is tested against the base year 1988. Accordingly, the length of an integration period starting in 1989 can be identified.

The trigger regression (2.2) is calculated while using all years between 1987 and 2000 as base year. There are 14 distinct estimations for the German vis-à-vis the French, Dutch, Danish and British bond yield correlations. As the yield series of Italy and Spain start in 1992, there are only 11 dummy parameters in equation (2.2). By evaluating all base years between 1992 and 2000, there are 9 different trigger regressions for the German vis-à-vis the Italian and Spanish correlations. Table 2.3 provides the overview of the length of each integration period. The base years are listed in the left column. If the year after the base year is identified as a trigger for bond market integration, this result is indicated in the row of the respective base year. Year numbers followed by a plus sign refer to the length of an integration period with increased average correlations. Year numbers followed by a minus sign refer to the length of a disintegration period with decreasing average correlations. An X refers to a year which neither initiates a period of higher nor lower bond market integration.[5]

Table 2.3: Trigger dummy regression estimates

		Correlation series					
		France	**Netherlands**	**Denmark**	**UK**	**Italy**	**Spain**
Base year	**1987**	X	X	X	X		
	1988	X	1 year -	X	1 year -		
	1989	**3 years +**	**14 years +**	**3 years +**	**14 years +**		
	1990	X	X	3 years -	X		
	1991	X	2 years +	1 year -	12 years +		
	1992	1 year -	X	X	X	1 year -	X
	1993	X	4 years -	X	2 years +	**10 years +**	X
	1994	X	**9 years +**	**3 years +**	2 years +	X	X
	1995	X	3 years +	2 years +	4 years -	2 years +	**8 years +**
	1996	1 year +	X	X	1 year -	X	7 years +
	1997	X	1 year +	2 years -	**6 years +**	1 year +	6 years +
	1998	X	3 years -	X	5 years +	1 year -	1 year -
	1999	X	**4 years +**	**4 years +**	4 years +	X	X
	2000	**3 years +**	3 years +	X	X	**3 years +**	X

Estimation results refer to equation (2.2). Year numbers indicate the length of a period in which a significant increase (+) or decrease (-) of average dynamic conditional correlations of French, Dutch, Danish, British, Italian and Spanish 10-year benchmark government bond yields vis-à-vis German 10-year benchmark government bond yields sustained as compared to the respective base year. As the time series for Italy and Spain only begin in 1992, equation (2.2) is estimated with only 11 instead of 16 year dummy variables and the rows referring to base years 1987 until 1991 remain blank. An X indicates that neither average correlations increased nor decreased as compared to the base year. Boldly highlighted cells indicate the starting point of a new integration wave. Statistical significance is confirmed for confidence levels of at least 10%, Wald t-statistics derived from heteroskedasticity-robust standard errors are used.

For several cases, Table 2.3 reveals that trigger years are often especially around the time in which a new stage of the EMU began. Long lasting integration periods thus seem to start with the single EMU stages. Interestingly, Table 2.3 also reveals for several cases that the initiated integration periods tend to end before or when a new stage of the EMU starts. Consequently, waves of bond market integration are triggered with the beginning of a new stage of the EMU

[5] For each of the 56 trigger dummy regressions for France, the Netherlands, Denmark and the UK, one intercept, one autoregressive parameter coefficient and 16 dummy coefficients are estimated. For the 18 trigger dummy regressions for Italy and Spain, the amount of dummy coefficients is reduced to 11. Because of clarity and space reasons, Table 2.3 does not provide an overview of all coefficient estimates and Wald t-statistics, but only provides an overview of length of the integration and disintegration periods.

but end before the next stage starts. With the beginning of the next stage, an own new wave begins.

This conclusion is only valid for some but not for all correlation series. It can be perfectly clearly described based on the Dutch results: The average correlation between the Dutch and the German government bond yields does not increase significantly between 1987 and 1989. Between 1987 and 1988, correlations remain constant as marked by the X. Between 1988 and 1989, correlations decrease for one year. Starting in 1990, a significant upswing in correlations as compared to the base year 1989 can be recognized. The average level of correlations in 1990 significantly exceeds the level of 1989. However, not only the average level of correlations in 1990 significantly exceeds the level of 1989, but also the average levels of the following years from 1991 until 2003. The year of the first EMU stage, 1990, thus initiates a permanent and non-reverting integration period. During the whole sample period, the correlation does never drop back to its average level of 1989.

By comparing the years 1990 and 1991, neither an increase nor a decrease in the correlation level can be recognized. Taking 1991 as base year, average correlation growth lasting for two years is identified. Between 1992 and 1993, correlations again remain constant. Since the trigger year 1990, average correlations thus steadily increase from year to year, or remain at the level reached in the last year. This result changes between 1993 and 1994. For the first time since 1990, the average correlation between Dutch and German government bond yields significantly decreases again. Clearly, the correlations do not fall back to their level in 1989, but below the level they already reach in 1993. This disintegration period sets a preliminary end to the integration progress. The first wave of integration, which is triggered in 1990, is terminated.

One year after the second stage of the EMU starts, however, a second wave of bond market integration is initiated. In the year 1995, the average correlations significantly exceed the average level of 1994. The same applies to the subsequent years between 1996 and 2003 in which the average correlation level remains on a higher level as compared to 1994. Thus, the year 1995 initiates a new long lasting and non-reverting integration period. This second wave of integration does not start exactly with the second stage of the EMU; however, a temporal reference to it can be seen.

From the trigger year 1995 onwards, average correlations again increase continuously or remain at the level of the prior year. Only between 1998 and 1999, this scheme is again interrupted. In the year 1999, the average correlation falls below the once reached level of 1998. Thus the second wave of integration stops after lasting from 1995 until 1999. However, in the year 2000, one year after the third stage of the EMU starts, the before terminated bond market integration process is again reaccelerated for a third time. For each year between 2000 and 2003, the average correlations between German and Dutch bond yields significantly increase as compared to the year 1999. One year after the third stage of the EMU starts, a third wave of bond market integration is identified.

The results for the correlation between German and Dutch bond yields are in line with the notion that single integration waves start with or shortly after a new stage of the EMU. The end of such a wave is reached with the subsequent stage. Each stage of the EMU seems to be a break point of the bond yield development in its own. The results for the other countries are not as strong as the Dutch results. Yet, in several cases, they agree that close to a new stage of the EMU, a new integration wave is triggered. They also agree in several cases that integration waves tend to stop before the next stage but then are reaccelerated again.

The boldly highlighted cells of Table 2.3 show the starting points of new integration waves for the different correlation series. For Denmark, a new integration wave also starts in close relation with each new EMU stage. For France and Italy, two integration waves start almost simultaneously with EMU stages, for Spain and the UK one integration wave does. In all cases, at least one period of disintegration falls between two integration waves. Though integration upswings are not always triggered exactly at the time of a new EMU stage, a chronological connection is acceptable in several cases. The argument that only the euro introduction itself is a break point for the European bond yield development seems inaccurate. With each stage of the EMU, the euro introduction becomes more likely. It is thus reasonable that after a short period of uncertainty regarding the new stage, the integration process is reinitiated again.

2.6 Reasons for bond market integration

The analysis so far documents the advances in bond market integration over the course of time. Since the EMU process began in July 1990, European bond markets became increasingly integrated. With some exceptions, the integration of the analyzed countries becomes stronger with each further stage of the EMU. In several cases, the beginning of each EMU stage triggers an own wave of bond market integration.

The analysis so far, however, does not tell anything about the reasons for the bond market integration. Bond markets become more integrated if the risk of the single countries converges. Then European information, which drives the joint risk of all countries, gains in importance over country specific information. Besides bond yield convergence, also a harmonization of bond yield movements is thus observable. From the beginning of the EMU in July 1990 until the euro introduction in January 1999, a lot of measures potentially relevant for such a harmonization and such a country specific risk convergence inside the euro area were realized. This subsection discusses three potential factors which might have contributed to the integration in government bond markets.

First, as fundamental values within the euro area converge, the countries become more similar and thus there is real integration. Fundamental assimilation encompasses for example the abolition of legal barriers for capital movements, economic convergence according to the Maastricht criteria or continuously increasing cooperation in monetary policy. Second, the introduction of the euro eliminates the exchange rate risk and transfers monetary policy to the ECB. As discussed in Santillan et al. (2000), the single currency additionally leads to a euro area wide harmonization of the institutional framework and the liquidity of the different countries' bond markets. Third, there is an ex ante expectance that distressed economies will always receive help from the rest of the euro area and thus each single country's risk is split in between all member states.

In Subsection 2.6.1, the DCC analysis is applied to accession countries of the EU enlargement in May 2004. With entering into the EU, the accession countries contractually agree on fundamentally developing the own economies in a way that the prerequisites for the introduction of the single currency can be met. Also, the accession attests that the new member states have already fulfilled the fundamental prerequisites for the EU. If fundamental convergence drives the bond market convergence, also this contractual affirmation and further obligation should be acknowledged by financial markets. Around May 2004, stronger bond market integration of the new member states should then be observable.

The DCC analysis is additionally applied to the Slovakian euro introduction in January 2009. The EU accession does not provide a schedule determining the exact timing of the euro introduction in the new member countries. Membership in the EU thus does neither eliminate the exchange rate risk nor provide any prediction on when this will eventually happen. An increase in bond yield correlations around the time of the accession is evidence that fundamental integration is an important driver of bond market integration. In comparison to that, an increase in bond yield correlations around the time of the euro introduction of an accession country is evidence that the elimination of the exchange rate risk or a bailout expectation for a new euro area member are important drivers of bond market integration.

In Subsection 2.6.2, the DCC analysis is applied to the major equity indices of Denmark, France, Germany, Italy, the Netherlands, Spain and the UK for the period during the EMU process. If the integration of the bond markets is only driven by an ex ante expectation that distressed countries within the euro area can rely on immediate help of the other countries, a similar integration progress should not be observable for the equity markets. As for equity markets a bailout is not expectable, integration should limit itself to the bond markets then. Clearly, equity indices of different countries are composed of different companies. Thus the indices have a different risk structure and are therefore not perfectly comparable. Still an increase in equity index correlations is nevertheless seen as at least weak evidence for fundamental integration or the elimination of the exchange rate risk as important drivers of bond market integration.

Based on the results from the studies on the accession countries and on the equity indices, some consideration about the main drivers of the bond market integration is possible. First, increasing bond yield correlations for the EU accession countries around May 2004 favor fundamental integration over eliminated exchange rate risk and a bailout expectation for euro area members as most relevant factor for bond market integration. Second, increasing bond yield correlations around the time of the euro introduction favor eliminated exchange rate risk and a bailout expectation over fundamental integration. Third, increasing equity index correlations favor fundamental integration and eliminated exchange rate risk over a bailout expectation. Subsection 2.6.3 provides a summarizing interpretation and sheds light on the most important factors contributing to the bond market integration.

2.6.1 Bond market integration of EU accession countries

2.6.1.1 EU accession 2004

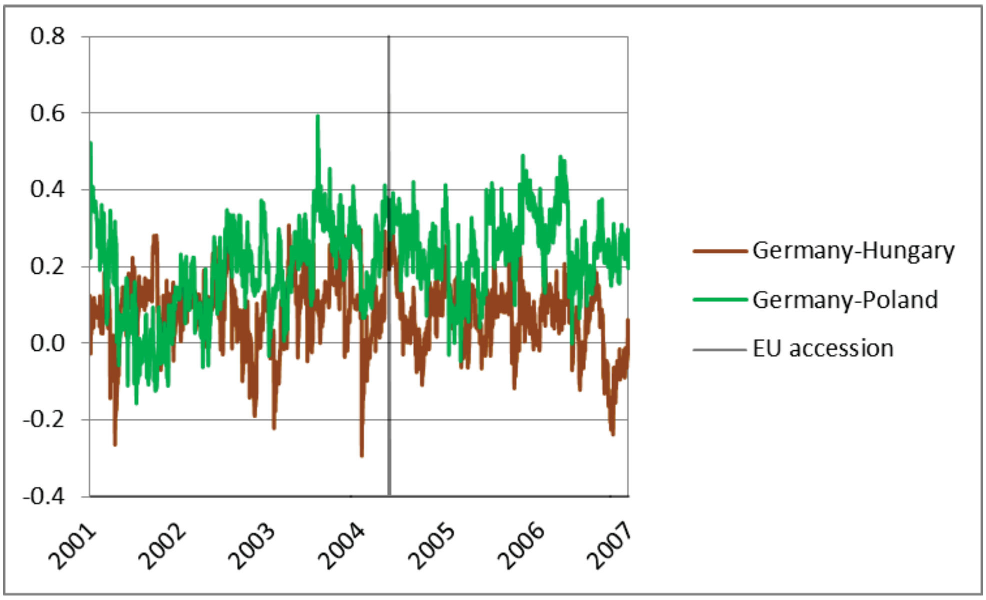
With the ratification of the Treaty of Accession on 01.05.2004, the biggest enlargement of the EU is completed. The accession not only confirms that the new member countries already fundamentally converged towards the euro area, but additionally contractually obliges them to further develop towards the fundamental prerequisites for the euro introduction.

The Treaty of Accession can be seen as the contractual counterpart to the Treaty on the European Union (Maastricht Treaty), which came into force two months before the second stage of the EMU in November 1993. With the Maastricht Treaty, the EMU countries also contractually agreed on working towards the euro introduction. Also the Maastricht Treaty both represents an acknowledgement that fundamental approximation between the EMU countries has already happened and an obligation for further fundamental convergence.

Yet, a major difference between the two situations is to be mentioned: While the exact timing of the euro introduction in January 1999 was publicly announced during the second stage of the EMU, the time of the euro introduction for the accession countries remained indeterminate. The countries analyzed in the following, Hungary and Poland, even by today did not yet introduce the euro. If there is an increase in bond yield correlation with Germany after the accession, only further fundamental integration prospects can cause this development, but not a soon expected euro introduction.

The DCC analysis for the accession countries is again conducted with week daily 10-year benchmark government bond yields, but now Hungary and Poland are added to the DCC system. The yield series start in January 2001 and end in December 2006. The countries and the starting point of the time series are chosen according to data availability and the economic importance and size of the selected accession economies. The time series are terminated early enough to ensure that the subsequent financial crisis does not have any impact on the yield development. Figure 2.3 shows the graph of the dynamic conditional correlations with the vertical line indicating the accession date. Table 2.4 provides the descriptive overview before and after the accession.[6]

Figure 2.3: Integration analysis of EU accession country bond markets



Dynamic conditional correlation estimates of 10-year benchmark government bond yields between Germany vis-à-vis Hungary and Poland between January 2001 and December 2006. The vertical line indicates the EU accession.

Table 2.4: Descriptive statistics of EU accession country correlation estimates

Correlation series		pre EU	EU
Germany-Hungary	Ø-correlation	0.084	0.063
	Stage %-growth		-26%
Germany-Poland	Ø-correlation	0.179	0.252
	Stage %-growth		41%

For each correlation series, the first row shows the average correlation estimates of the Hungarian and Polish vis-à-vis the German 10-year benchmark government bond yields before and after the EU accession. The second row shows the percentage growth of average correlations in between the two periods.

[6] For the DCC model specification of the EU accession country bond market analysis refer to Table B.2.2 of Appendix B in Subsection 2.8.2. The correlation development of France, the Netherlands, Denmark, the UK, Italy and Spain around the time of the EU accession in 2004 is not discussed here. Thus, Figure 2.3 and Table 2.4 do not display the dynamic conditional correlation estimates for these six countries for clarity reasons.

A first interesting conclusion can be drawn by comparing Figure 2.2 and Table 2.1 with these results for the accession countries. The bond market integration of the accession countries displays a highly lower degree as the bond market integration within the EMU countries. Additionally, each new stage of the EMU process resulted in a visible upswing of bond yield correlations, but the same does not apply for the two enlargement countries around May 2004. This comparison is in particular interesting for Denmark and the UK, as also these two countries neither have introduced the euro yet, nor have a specific schedule to do so. Thus, the different currencies alone cannot explain these differences between the EMU foundation and the EU accession.

The second result sheds some light on potential reasons for the bond market integration. For the whole time frame, the dynamic conditional correlations remain fairly stable. From visual inspection, there is no or at most minor evidence that the EU accession does have any major impact on the bond yield development. Fundamental convergence thus seems to be of minor importance for the bond market integration. This result can be confirmed statistically. The estimation procedure is similar to Subsection 2.5.1 and builds on equation (2.3).

$$\rho_t = \tau + \phi\rho_{t-1} + \varpi D_{1,t} + u_t \tag{2.3}$$

The autoregressive parameters ρ_t are the dynamic conditional correlation estimates of the DCC analysis for the accession countries, τ, ϕ and ϖ the parameters to be estimated and u_t the error term. $D_{1,t}$ is a dummy variable representing the time after the EU accession and takes a value of one between 01.05.2004 and 31.12.2006 and zero otherwise. A significantly positive dummy parameter provides evidence for an increase in bond market integration after entering the EU. Table 2.5 presents the estimation results.[7]

For Poland, the dummy parameter is insignificant, for Hungary it is even significantly negative. The graphical results are confirmed. The impact of the EU accession for the bond market integration is highly distinct as compared to the impact of the EMU stages. Bond yield correlations do not increase with the accession to the EU. Solely based on the results of this

[7] Uniformly to Table 2.2, because of clarity and space reasons Table 2.5 only shows the interpretable coefficient estimates.

subsection, the convergence in fundamental values seems to play a minor role for the bond market integration.

Table 2.5: EU accession dummy regression estimates

Correlation series	Accession
Germany-Hungary	-0.004*
	(-1.913)
Germany-Poland	0.009
	(1.585)

Dummy parameter estimates testing the contribution of the EU accession to the bond market integration from equation (2.3) are shown for dynamic conditional correlation series of Hungarian and Polish 10-year benchmark government bond yields vis-à-vis German 10-year benchmark government bond yields. Significantly positive coefficients indicate that average bond market integration between Germany and the respective counterpart increases as compared to the time before the EU accession. Upper numbers refer to the coefficient estimates. *, ** and * denote rejection of H0 (the parameter being equal to zero) and statistical significance at the 10%, 5% and 1% confidence level, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses.**

2.6.1.2 Slovakian euro introduction 2009

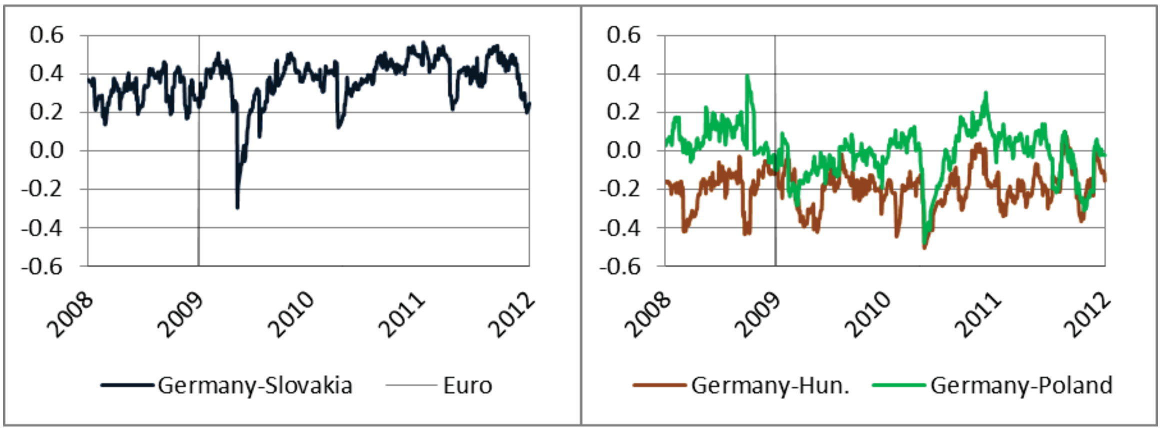
In order to analyze if the introduction of the euro or the expectation thereof causes the bond market integration, again the correlation development of accession countries can be studied. In January 2009, Slovakia was the fourth accession country to introduce the single currency. With Slovenia in 2007 and Malta and Cyprus in 2008, three other enlargement countries introduced the euro before Slovakia, yet only for Slovakia comparable government bond yields can be obtained before the euro introduction. Another DCC analysis with week daily 10-year benchmark government bond yields is conducted with Slovakia as additional sample country. The Slovakian yield series is available from January 2008 and ends in December 2011 and thus captures a time frame before and after the euro introduction in January 2009.

Figure 2.4 and Table 2.6 present the overview of the dynamic correlation development.[8] For means of comparison, a second subplot with the correlation development for Hungary and

[8] The Slovakian 10-year benchmark government bond yields are provided on the BOFIT database. For the DCC model specification of the Slovakian euro introduction analysis refer to Table B.2.3 of Appendix B in Subsection 2.8.2. Again, the correlation development of France, the Netherlands, Denmark, the UK, Italy and Spain around the time of the Slovakian euro introduction in 2009 is not discussed here. Thus, also Figure 2.4 and Table 2.6 do not display the dynamic conditional correlation estimates for these six countries for clarity reasons.

Poland is additionally provided. The vertical line indicates the time of the euro introduction in Slovakia.

Figure 2.4: Integration analysis of bond markets at the time of the Slovakian euro introduction



Dynamic conditional correlation estimates of 10-year benchmark government bond yields between Germany vis-à-vis Slovakia (left subplot) and Hungary and Poland (right subplot) between January 2008 and December 2011. The vertical line indicates the euro introduction in Slovakia.

Table 2.6: Descriptive statistics of correlation estimates at the time of the Slovakian euro introduction

Correlation series euro introduction		**Pre euro**	**Euro**
Germany-Slovakia	Ø-correlation	0.316	0.378
	Stage %-growth		19%
Correlation series no euro introduction		**Pre euro**	**Euro**
Germany-Hungary	Ø-correlation	-0.195	-0.193
	Stage %-growth		-1%
Germany-Poland	Ø-correlation	0.081	-0.032
	Stage %-growth		-140%

For each correlation series, the first row shows the average correlation estimates of the Slovakian, Hungarian and Polish vis-à-vis the German 10-year benchmark government bond yields before and after the euro introduction in Slovakia. The second row shows the percentage growth of average correlations in between the two periods.

Clear differences can be recognized for Slovakia and the control countries. For Slovakia, the average correlations are higher over the whole observation period. With the euro introduction, the bond yield correlation increases even further. For Hungary and Poland, which did not introduce the euro, the level of the correlations decreases on average. The euro introduction seems to play a crucial role for the rising bond market integration in Slovakia.

This notion can again be tested statistically. The test equation is identical to (2.3), however in this case $D_{1,t}$ represents the time frame after the euro introduction in Slovakia and takes a value of one between 01.01.2009 and 31.12.2011 and zero otherwise. A significantly positive dummy parameter indicates that bond yield correlation increases with the euro. Table 2.7 shows the estimation results.[9]

Table 2.7: Euro introduction dummy regression estimates

Correlation series	**Euro introduction**
Germany-Slovakia	0.003***
	(3.264)
Germany-Hungary	-0.0002
	(-0.075)
Germany-Poland	-0.003
	(-0.818)

Dummy parameter estimates testing the contribution of the Slovakian euro introduction to the bond market integration from equation (2.3) are shown for dynamic conditional correlation series of Slovakian, Hungarian and Polish 10-year benchmark government bond yields vis-à-vis German 10-year benchmark government bond yields. Significantly positive coefficients indicate that average bond market integration between Germany and the respective counterpart increases as compared to the time before the euro introduction. Upper numbers refer to the coefficient estimates. *, ** and * denote rejection of H0 (the parameter being equal to zero) and statistical significance at the 10%, 5% and 1% confidence level, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses.**

The dummy parameter for Slovakia is significantly positive, while the parameters for the two non-euro control countries are insignificant. An increase of bond yield correlations after the euro introduction is confirmed. The results favor the euro as a main contributor to the bond market integration. Solely based on this subsection, the risk convergence of the Slovakian government bond market with its German counterpart comes from eliminated exchange rate risk or the expectation that also the new euro area member will be bailed out, once it is in distress.

[9] Uniformly to Table 2.2, because of clarity and space reasons Table 2.5 only shows the interpretable coefficient estimates.

2.6.2 Equity data

The harmonization of movements of equity indices is investigated for Denmark, France, Germany, Italy, the Netherlands, Spain and the UK for the time of the EMU process. In all cases, a major performance index is applied to the analysis.[10] Clearly the composition of the equity indices varies from country to country, but nevertheless they serve as a reasonable approximation for the evaluation of equity market integration.

The time frame of the equity analysis starts in January 1992 and ends in December 2003 for all seven countries. Matching the time range to the bond market analysis is not possible for each country due to data availability problems. Additionally, the August Putsch of 1991 in the Soviet Union shows an extreme influence on the development in the equity markets. In order to avoid this deviation, which does not show up in the bond market development, this anomaly is excluded.

Dynamic conditional correlations of the six countries' equity indices vis-à-vis the German DAX 30 are estimated according to the DCC model. Figure 2.5 presents the correlation development, Table 2.8 the descriptive overview.[11]

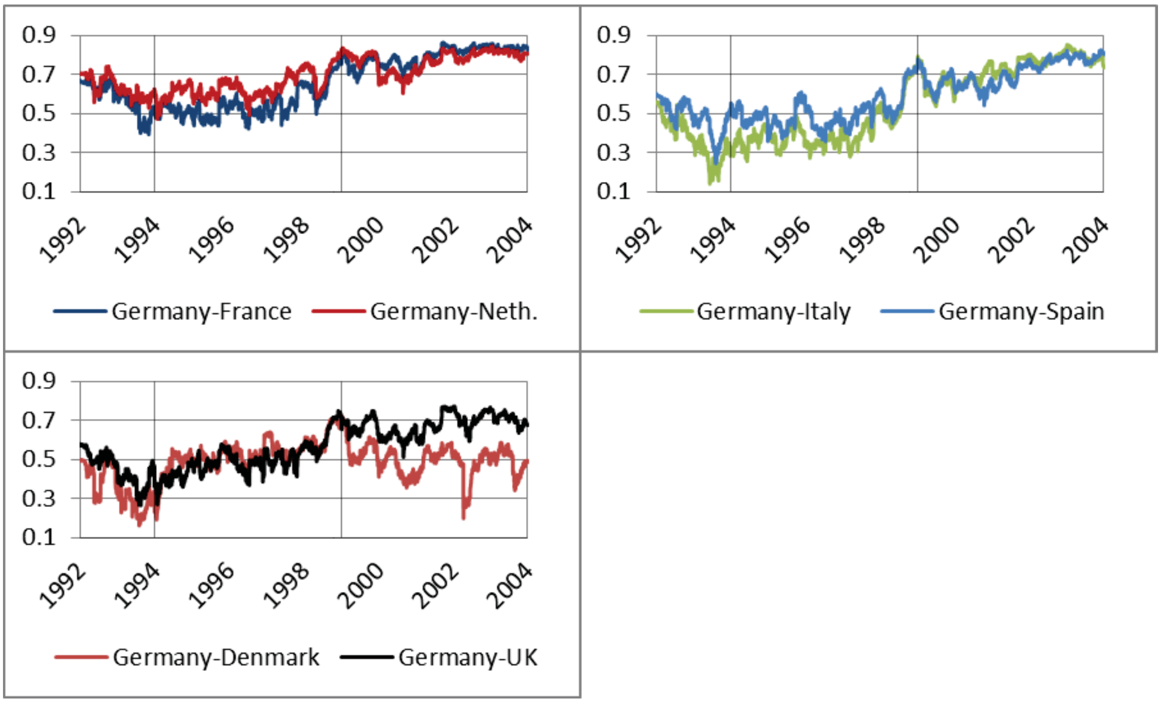
The graphical results demonstrate some equity market integration. European information gains in importance as joint driver of the single equity indices as compared to country specific information. Even though, the risk and return structure of the different equity indices varies, a tendency towards risk convergence is observable. With the exception of Denmark since the beginning of the third stage of the EMU, a general increase in correlation coefficients can be confirmed. Yet, this correlation surge is by far not as complete as for the bond markets and might furthermore be driven by the already discussed globalization effect to at least some extent.

If the integration of the bond markets is only driven by an ex ante expectation that distressed countries can rely on immediate help of other countries of the euro area, a similar increase in

[10] The equity indices are Copenhagen KFX for Denmark, CAC 40 for France, DAX 30 for Germany, FTSE Italia for Italy, AEX for the Netherlands, IBEX 35 for Spain and FTSE 100 for the UK.
[11] For the DCC model specification of the EMU equity market analysis refer to Table B.2.4 of Appendix B in Subsection 2.8.2.

correlations should not be observable for the equity markets. As for equity markets a bailout is not expectable, integration should limit itself to the bond markets. The equity market analysis, however, does indicate that there is some evidence for equity market integration as well. This equity integration development clearly lacks the completeness of the bond market integration, but is nevertheless observable. Solely based on the results of this subsection, an ex ante bailout expectation for euro area members thus is not highly favored. Fundamental convergence or the eliminated exchange rate risk is advocated as at least minor driver of the integration process instead.

Figure 2.5: Integration analysis of EMU equity markets



Dynamic conditional correlation estimates of major equity indices between Germany vis-à-vis France and the Netherlands (upper left subplot), Denmark and the UK (lower left subplot) and Italy and Spain (upper right subplot) between January 1992 and December 2003. Vertical lines indicate the second and the third stage of the EMU.

2.6.3 Summarizing interpretation

The results from the last three subsections do not show a completely clear picture of the reasons for the bond market integration. Some cautious conclusion, however, can be drawn:

The introduction of the euro as single currency and the subsequent consequences for the exchange rate risk, the monetary policy and the market liquidity seem to be a very important driver of the bond market integration. With the Slovakian euro introduction, bond market integration rallied. With the Slovakian analysis alone, a distinction between the elimination of the exchange rate risk and a potential ex ante expectation of a euro area wide bailout is not possible. Yet, the additional results of the equity analysis do not strongly favor the idea of the ex ante bailout expectation. In combination, the two analyses advocate the elimination of exchange rate risk as important driver of bond market integration.

Table 2.8: Descriptive statistics of EMU equity correlation estimates

Correlation series		Stage 1	Stage 2	Stage 3
Germany-France	Ø-correlation	0.580	0.547	0.796
	Stage %-growth		-6%	45%
	2-Stage %-growth			37%
Germany-Netherlands	Ø-correlation	0.634	0.639	0.774
	Stage %-growth		1%	21%
	2-Stage %-growth			22%
Germany-Denmark	Ø-correlation	0.353	0.530	0.496
	Stage %-growth		50%	-6%
	2-Stage %-growth			41%
Germany-UK	Ø-correlation	0.451	0.497	0.679
	Stage %-growth		10%	37%
	2-Stage %-growth			51%
Germany-Italy	Ø-correlation	0.367	0.415	0.730
	Stage %-growth		13%	76%
	2-Stage %-growth			99%
Germany-Spain	Ø-correlation	0.482	0.503	0.710
	Stage %-growth		4%	41%
	2-Stage %-growth			47%

For each correlation series, the first row shows the average correlation estimates of the French, Dutch, Danish, British, Italian and Spanish vis-à-vis the German major equity indices within the three stages of the EMU. The second row shows the percentage growth of average correlations from stage to stage and the third row shows the percentage correlation growth from stage one to stage three.

Irrevocably fixed exchange rates, however, cannot explain the bond market integration alone. Since the EMU process started the bond market integration of Denmark and the UK did not advance as strongly as compared to France, the Netherlands, Italy and Spain. Yet, an increase in bond market integration, which lies above the globalization effect, is clearly observable. Denmark pegs the Danish krone to the euro, the British pound floats freely. For both countries, a schedule of a potential euro introduction is not foreseeable. Thus, there need to be different factors than the eliminated exchange rate risk which explain the bond market integration during the EMU process.

Also a bailout expectation of euro area members cannot help explain the specific case of Denmark and the UK. For the euro area countries, however, it may also be contributing to further bond market integration. The results for the euro introduction analysis confirm this thesis, yet the equity market analysis does not. The expectation of a bailout provision seems to be of minor importance as compared to the eliminated exchange rate risk.

Finally, fundamental integration as driver of bond market integration is valid for both euro area and non-euro area countries. Thus, risk convergence caused by convergence of fundamental values likely is a factor contributing to bond market integration. The estimation results from Subsection 2.6 are ambiguous, with the equity analysis backing the notion of some fundamental integration and the EU accession analysis contradicting the notion of fundamental integration. Furthermore, fundamental integration can explain bond market integration for Denmark and the UK, however, it was not able to cause equally complete bond market integration as compared to the euro area countries. Thus, also the significance of fundamental integration seems to fall short of the importance of the eliminated exchange rate risk.

2.7 Conclusion

The analysis provides further insights regarding the bond market integration during the EMU process. DCC models are estimated in order to evaluate the degree of European bond market integration. A clear development towards greater bond market integration is confirmed. In several cases, the integration of the sample countries becomes stronger with each further stage of the EMU and integration waves frequently start almost simultaneously with new EMU stages. The results also depict that regional differences in the degree and pace of integration remain. This is especially important for the non-euro area countries Denmark and the UK. While the two countries show a strong tendency towards bond market integration during the first two stages of the EMU, they do not reach a comparably high degree in the third stage. Non-participation in the third stage leads to a slower integration pace.

Additionally, the analysis sheds light on the reason for the bond market integration. In that, DCC models are estimated for EU accession countries and EMU equity markets. Three potential reasons of the EMU bond market integration are evaluated: Fundamental integration, elimination of currency fluctuations and ex ante bailout expectations for euro area members. Though no strong conclusions can be drawn, the results are in favor of eliminated exchange rate risk as a major driver of bond market integration. Fundamental integration and an ex ante expectation of bailout provisions for distressed euro area members are also likely reasons but seem to be of minor importance.

2.8 Appendix

2.8.1 Appendix A: The DCC model

DCC models are introduced by Engle (2002) and Engle and Sheppard (2001). They belong to the class of MGARCH models. DCC models are used to estimate time-varying conditional volatilities and conditional correlations of the time series of interest. Dynamic correlations are especially useful when analyzing correlation developments over time.

DCC modeling requires two-step estimation. In the first step, the conditional variance $h_{i,t}$ of each analyzed time series is estimated with separate univariate GARCH models. In the second step, the standardized residuals from the univariate GARCH models are used to estimate the conditional correlation matrix $\mathbf{R_t}$ of the complete set of time series. In order to qualify for the DCC model, the vector of input variables $\mathbf{r_t}$ needs to have a mean value of zero, i.e. an expected value of zero for the realization of each time series at time t. The input vector $\mathbf{r_t}$ is characterized according to (A.2.1) with the time varying covariance matrix $\mathbf{H_t}$ specified in (A.2.2).

$$\mathbf{r_t} \sim N(0, \mathbf{H_t}) \qquad \text{(A. 2.1)}$$

$$\mathbf{H_t} = \mathbf{D_t R_t D_t} \qquad \text{(A. 2.2)}$$

$\mathbf{R_t}$ represents the time-variant correlation matrix. The main diagonal of $\mathbf{R_t}$ consists of ones. Non-diagonal elements are correlation coefficients between the different elements of the input vector $\mathbf{r_t}$ at time t. $\mathbf{D_t}$ is a diagonal matrix with the conditional standard deviations $\sqrt{h_{i,t}}$ of the input vector $\mathbf{r_t}$ as elements. In the first estimation step, these conditional variances $h_{i,t}$ for the $i = 1, \dots, N$ elements of the input vector $\mathbf{r_t}$ are estimated with N separate univariate GARCH models according to (A.2.3).

$$h_{i,t} = \alpha_i + \sum_{p=1}^{P} \beta_{i,p}\, r_{i,t-p}^2 + \sum_{q=1}^{Q} \gamma_{i,q}\, h_{i,t-q} \qquad \text{(A. 2.3)}$$

The conditional variances depend on lagged realizations of $r_{i,t}$ - i.e. on shock elements – and on lagged conditional variances $h_{i,t}$ – i.e. on decay elements. α_i denotes the intercept of the GARCH equation, the β_i's are the coefficients of the shock parameters and the γ_i's are the coefficients of the decay parameters.

From the estimated conditional variances $h_{i,t}$ of equation (A.2.3) the standardized GARCH residual vector $\boldsymbol{\varepsilon}_\mathbf{t}$ is subsequently derived according to (A.2.4). Each single GARCH residual $\varepsilon_{i,t}$ is calculated by dividing each input element $r_{i,t}$ with its own estimated conditional standard deviation $\sqrt{h_{i,t}}$. The standardized GARCH residual vector $\boldsymbol{\varepsilon}_\mathbf{t}$ is thus volatility adjusted.

$$\boldsymbol{\varepsilon}_\mathbf{t} = \mathbf{D}_\mathbf{t}^{-1}\mathbf{r}_\mathbf{t} \qquad (A.2.4)$$

In the second estimation step, the conditional covariance $\mathbf{Q}_\mathbf{t}$ of the standardized GARCH residuals $\boldsymbol{\varepsilon}_\mathbf{t}$ is estimated. The volatility adjusted residuals $\boldsymbol{\varepsilon}_\mathbf{t}$ are applied to the multivariate GARCH equation according to (A.2.5).

$$\mathbf{Q}_\mathbf{t} = \left(1 - \sum_{m=1}^{M} \delta_m - \sum_{n=1}^{N} \zeta_n\right)\widehat{\mathbf{Q}} + \sum_{m=1}^{M} \delta_m \left(\boldsymbol{\varepsilon}_\mathbf{t-m}\boldsymbol{\varepsilon}'_\mathbf{t-m}\right) + \sum_{n=1}^{N} \zeta_n \, \mathbf{Q}_\mathbf{t-n} \qquad (A.2.5)$$

Comparable to the estimation of conditional variances in (A.2.3), the conditional covariance depends on lagged realizations of the covariance $\boldsymbol{\varepsilon}_\mathbf{t}\boldsymbol{\varepsilon}'_\mathbf{t}$ derived from the realizations of the GARCH residual vector and the lagged conditional covariance $\mathbf{Q}_\mathbf{t}$. The δ's are the coefficients of the shock parameters and the ζ's are the coefficients of the decay parameters.

$\widehat{\mathbf{Q}}$ is the unconditional covariance matrix of the GARCH residual $\boldsymbol{\varepsilon}_\mathbf{t}$. It ensures that the multivariate estimation generates well defined conditional covariance matrices. The unconditional covariance matrix $\widehat{\mathbf{Q}}$ is positive definite and the lagged shocks $\boldsymbol{\varepsilon}_\mathbf{t-m}\boldsymbol{\varepsilon}'_\mathbf{t-m}$ are positive semi-definite. Consequently, also the conditional covariance matrix $\mathbf{Q}_\mathbf{t}$, as a weighted average of a positive definite and a positive semi-definite matrix, is positive definite. Engle and Sheppard (2001) provide exact conditions for this result.

The estimated conditional covariance matrix $\mathbf{Q_t}$ of equation (A.2.5) finally needs to be converted to the conditional correlation matrix $\mathbf{R_t}$. The necessary normalization is shown in (A.2.6). The auxiliary matrix $\mathbf{Q_t^*}$ is a diagonal matrix with the square roots of the diagonal elements of the conditional covariance matrix $\mathbf{Q_t}$ - i.e. the conditional standard deviations of the GARCH residual vector $\boldsymbol{\varepsilon_t}$ - as its elements. Due to multiplying $\mathbf{Q_t}$ with the inverse of $\mathbf{Q_t^*}$ from the left and from the right, the non-diagonal elements of $\mathbf{R_t}$ are a conditional covariance divided by the product of conditional standard deviations, i.e. the estimated dynamic conditional correlation coefficients between the analyzed time series.

$$\mathbf{R_t} = \mathbf{Q_t^{*-1} Q_t Q_t^{*-1}} \qquad (\mathrm{A.2.6})$$

The two-step DCC model is calculated with maximum likelihood estimation. If the input vector $\mathbf{r_t}$ is not multivariate normal, quasi maximum likelihood is applied. Under very general conditions, the (quasi) maximum likelihood estimates are consistent and asymptotically normal, as described in White (1994). Additionally, Bollerslev-Wooldridge consistent standard errors can be calculated according to Engle and Sheppard (2001). Consistent Wald t-tests on the estimated parameters can be conducted.

2.8.2 Appendix B: DCC model specification

DCC modeling requires mean zero input variables according to (A.2.1). In order to avoid spurious regressions, stationarity needs to be guaranteed. All data applied to the model is filtered for unit roots by differencing and the resulting stationary variables are subsequently demeaned.

In the first DCC estimation step, each country's conditional volatility process represented by equation (A.2.3) is estimated. The lag order of each univariate GARCH-equation needs to be specified separately according to the input data. A general version of each conditional volatility model is estimated and GARCH-coefficients are evaluated with Wald t-tests. Removing all insignificant lags reveals the final specification.

In the second DCC estimation step, the GARCH residuals from the first step are used to estimate the conditional covariance process according to equation (A.2.5). Also the lag order of the multivariate GARCH-equation needs to be specified according to the data. As in the univariate case, Wald t-tests are applied to the coefficients of a general version of the conditional covariance model. Bollerslev-Wooldridge consistent standard errors as documented in Engle and Sheppard (2001) need to be used, in order to perform consistent Wald t-tests. Removing insignificant lags again reveals the final specification.

The adequacy of the univariate GARCH-specifications is tested with the ARCH-LM test, which checks each country's GARCH-residuals for remaining conditional heteroskedasticity. The test evaluates an H0 of no conditional heteroskedasticity against an H1 of remaining conditional heteroskedasticity. A sufficiently high F-statistic leads to rejection of the H0.

The suitability of estimating a dynamic conditional correlation process depends on the properties of the correlation structure. Equations (A.2.5) and (A.2.6) are used to estimate dynamics of correlations. This is only necessary, if there are correlation dynamics at all. If correlations between assets are constant, as assumed in Bollerslev (1990), estimation of a dynamic structure becomes redundant. It is thus essential to investigate if the data allows for the estimation of correlation dynamics. Engle and Sheppard (2001) propose a test which evaluates an H0 of constant conditional correlation against an H1 of dynamic conditional correlation. A sufficiently high F-statistic rejects the H0. The OLS based test demonstrates good size and power properties against local alternatives.

The DCC specification and the diagnostic test results for all estimations are provided within the next four tables: Table B.2.1 summarizes the estimation results for the EMU bond yield analysis, Table B.2.2 for the bond yield analysis of the EU accession, Table B.2.3 for the bond yield analysis of the euro introduction in Slovakia and Table B.2.4 for the EMU equity analysis. All tables can be read as follows, with table specific information in the respective caption:

The rows with the country names represent the estimation results for each country's univariate GARCH equation (A.2.3). The columns denoted as ARCH represent the estimation results for the lagged shocks, the columns denoted as GARCH for the lagged variances. The numbers in parentheses below the parameter estimates refer to t-statistics derived from Wald t-tests.

The row labeled with DCC represents the estimation results for the multivariate covariance equation (A.2.5). Also here, upper numbers are the parameter estimates for lagged shocks and lagged covariance, lower numbers in parenthesis are t-statistics derived from Wald t-tests. The t-statistics of the multivariate equation are calculated using modified standard errors, which is a requirement in the multivariate equation for consistent t-statistics, as described in Engle and Sheppard (2001).

The numbers in parentheses directly under the country name refer to the estimated F-statistic of the specific country's ARCH-LM test. The number in parenthesis below "DCC" refers to the estimated F-statistic of the OLS based test for the correlation dynamics.

An X marks that for the particular time series, the relevant ARCH or GARCH parameter is insignificant and dropped from the equation. For the estimations represented by Table B.2.1 and B.2.2, all ARCH 2 parameters are insignificant and thus the whole column is dropped.

Table B.2.1: DCC specification and diagnostic test results for the EMU analysis of bond yields

	ARCH 1	GARCH 1	GARCH 2
Germany	0.061***	0.923***	X
(0.322)	*(6.027)*	*(70.453)*	
France	0.074***	0.902***	X
(0.811)	*(5.996)*	*(53.596)*	
Netherlands	0.086***	0.894***	X
(0.463)	*(4.661)*	*(40.039)*	
Denmark	0.088***	0.894***	X
(0.265)	*(4.318)*	*(36.754)*	
UK	0.071***	0.348**	0.567***
(0.105)	*(3.418)*	*(2.168)*	*(3.756)*
DCC	0.031***	0.257***	0.712***
*(723.074)****	*(6.167)*	*(5.563)*	*(15.126)*
Italy	0.097***	0.903***	X
(0.992)	*(5.157)*	*(48.034)*	
Spain	0.078***	0.920***	X
(0.864)	*(3.637)*	*(44.881)*	
DCC	0.033***	0.281***	0.685***
*(1150.305)****	*(10.330)*	*(5.736)*	*(14.016)*
US	0.044***	0.934***	X
(0.279)	*(4.284)*	*(69.701)*	
DCC	0.009***	0.990***	X
*(51.754)****	*(2.905)*	*(243.059)*	

Rows 1-6 refer to a sample ranging from January 1987 to December 2003, rows 7-9 to a sample ranging from January 1992 to December 2003, rows 10-11 to a sample ranging from January 1987 to December 2003 and covering the US as globalization control.

Rows 1-5, 7-8 and 10 display ARCH and GARCH coefficients for the univariate conditional volatility equation (A.2.3) for Germany, France, the Netherlands, Denmark, the UK, Italy, Spain and the US. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Rows 6, 9 and 11 display ARCH and GARCH coefficients for the multivariate conditional covariance equation (A.2.5). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. Lower numbers in parentheses below "DCC" refer to F-statistics derived from the OLS-test for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

Table B.2.2: DCC specification and diagnostic test results for the EU accession analysis of bond yields

	ARCH 1	GARCH 1	GARCH 2
Germany	0.023***	0.976***	X
(0.765)	*(2.800)*	*(99.024)*	
France	0.025***	0.970***	X
(1.344)	*(2.600)*	*(70.715)*	
Netherlands	0.028***	0.965***	X
(0.581)	*(2.726)*	*(64.090)*	
Denmark	0.025***	0.954***	X
(0.990)	*(2.873)*	*(53.393)*	
UK	0.034	0.211**	0.730***
*(8.366)****	*(1.622)*	*(2.094)*	*(7.160)*
Italy	0.030***	0.962***	X
(0.383)	*(2.767)*	*(61.281)*	
Spain	0.026***	0.969***	X
(0.824)	*(2.646)*	*(70.633)*	
Hungary	0.208***	0.575***	X
(0.424)	*(2.739)*	*(3.472)*	
Poland	0.073***	0.919***	X
(1.729)	*(3.351)*	*(36.613)*	
DCC	0.055***	0.363***	0.531***
*(2278.671)****	*(5.456)*	*(3.245)*	*(4.538)*

All rows refer to a sample ranging from January 2001 to December 2006.

Rows 1-9 display ARCH and GARCH coefficients for the univariate conditional volatility equation (A.2.3) for Germany, France, the Netherlands, Denmark, the UK, Italy, Spain, Hungary and Poland. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Row 10 displays ARCH and GARCH coefficients for the multivariate conditional covariance equation (A.2.5). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. The lower number in parentheses below "DCC" refers to the F-statistic derived from the OLS-test for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

Table B.2.3: DCC specification and diagnostic test results for the Slovakian euro introduction analysis of bond yields

	ARCH 1	ARCH 2	GARCH 1	GARCH 2
Germany	0.107***	X	0.249**	0.620***
(1.827)	*(2.613)*		*(2.562)*	*(6.160)*
France	0.033***	X	0.963***	X
(1.720)	*(3.758)*		*(96.229)*	
Netherlands	0.037***	X	0.955***	X
(0.116)	*(2.875)*		*(57.324)*	
Denmark	0.035**	X	0.956***	X
(1.635)	*(2.199)*		*(40.480)*	
UK	0.067***	X	0.279**	0.629***
*(3.191)***	*(2.881)*		*(2.014)*	*(4.652)*
Italy	0.258***	0.290**	0.375***	X
(1.238)	*(2.905)*	*(2.226)*	*(3.129)*	
Spain	0.118***	X	0.882***	X
(0.264)	*(4.822)*		*(27.176)*	
Hungary	0.124***	X	0.871***	X
(0.197)	*(3.646)*		*(21.626)*	
Poland	0.116***	X	0.884***	X
(1.190)	*(5.375)*		*(28.011)*	
Slovakia	0.251**	X	0.623***	X
(0.090)	*(2.312)*		*(4.923)*	
DCC	0.031***	X	0.933***	X
*(3819.811)****	*(4.609)*		*(37.676)*	

All rows refer to a sample ranging from January 2008 to December 2011.

Rows 1-10 display ARCH and GARCH coefficients for the univariate conditional volatility equation (A.2.3) for Germany, France, the Netherlands, Denmark, the UK, Italy, Spain, Hungary, Poland and Slovakia. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Row 11 displays ARCH and GARCH coefficients for the multivariate conditional covariance equation (A.2.5). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. The lower number in parentheses below "DCC" refers to the F-statistic derived from the OLS-test for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

Table B.2.4: DCC specification and diagnostic test results for the EMU analysis of equity indices

	ARCH 1	ARCH 2	GARCH 1	GARCH 2
Germany	0.094***	X	0.906***	X
(0.631)	*(9.382)*		*(92.964)*	
France	0.056***	X	0.944***	X
(0.717)	*(7.728)*		*(137.808)*	
Netherlands	0.039**	0.062***	0.898***	X
(0.969)	*(2.203)*	*(3.030)*	*(89.320)*	
Denmark	0.072***	X	0.928***	X
(1.734)	*(5.183)*		*(61.886)*	
UK	0.069***	X	0.930***	X
(0.183)	*(5.940)*		*(80.420)*	
Italy	0.099***	0.074***	0.067**	0.760***
(2.100)	*(5.583)*	*(3.654)*	*(2.007)*	*(23.714)*
Spain	0.041***	0.046**	0.913***	X
(0.791)	*(2.666)*	*(2.207)*	*(67.085)*	
DCC	0.015***	X	0.557***	0.426***
*(160.091)****	*(5.505)*		*(4.766)*	*(3.658)*

All rows refer to a sample ranging from January 1992 to December 2003.

Rows 1-7 display ARCH and GARCH coefficients for the univariate conditional volatility equation (A.2.3) for Germany, France, the Netherlands, Denmark, the UK, Italy and Spain. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Row 8 displays ARCH and GARCH coefficients for the multivariate conditional covariance equation (A.2.5). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. The lower number in parentheses below "DCC" refers to the F-statistic derived from the OLS-test for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

With the exception of the univariate GARCH estimation for the UK in Table B.2.2 and B.2.3, the null hypothesis of no remaining heteroskedasticity is not rejected. Thus, again with the exception of the UK, the univariate GARCH-residuals do not show signs of remaining conditional heteroskedasticity. Also with different specifications of the British univariate GARCH equation, remaining heteroskedasticity could not be avoided. As the univariate conditional volatility development of the UK is not analyzed for the EU accession in 2004 and the Slovakian euro introduction in 2009, this unfortunate specification problem of the UK does not have any impact on the results. For each multivariate conditional covariance equation, the null hypothesis of constant conditional correlation is clearly rejected. Estimation of a dynamic correlation structure thus is indeed necessary.

Chapter 3

Contagion risk from Greece during the European debt crisis: Correlation and rating based evidence

3.1 Preface: Contagion

The concept of contagion is a very broad one. Generally, problems of one market participant spread to other members of the system and thus generate problems for them. Reasons for contagious pressures are manifold and may range from fundamental interrelations between market participants to non-fundamentally justified sentiment driven extrapolation of bad information from one market participant to another. Contagion can affect both companies, as discussed in Chapter 4, or whole economies, as discussed in this chapter. Analyzing the economy level, contagion can generally be described as follows: Without the existence of the infecting economy, the infected economies would be better off.

During the European debt crisis, the threat of contagion emanating from Greece was an omnipresent discussed topic. Measures taken in order to contain the crisis were immediately evaluated against the background of Greece's potential to infect other euro area members. A vivid example represents a speech of the European Commissioner for Economic and Monetary Policy, Olli Rehn, addressed to the European Parliament on 05.05.2010, shortly after the first rescue package for Greece was agreed by the euro area, IMF and ECB:

"The financial support gives Greece breathing space to restore the sustainability of its public finances, as well as its overall economic competitiveness. This is needed not only for Greece, but in order to safeguard financial stability in Europe, to avoid the bush-fire in Greece turning into a forest fire in Europe. Financial stability is necessary for Europe's ongoing economic recovery for sustainable growth and job creation. Some of you mentioned the contagion effect and concerns related to other countries of the euro area or of the European Union. No one can deny that there have been tensions in the financial markets in recent days and weeks but, as in all financial markets, there is significant overshooting. All euro-area Member States are taking measures to consolidate their public finances, not least Portugal and Spain." (Rehn, 2010)

Since the end of 2009, several euro area countries have experienced refinancing problems for their sovereign debt in terms of higher yields. While this European sovereign debt crisis has its origin in Greece, other countries have meanwhile experienced very similar problems.

Chapter 3 analyzes the question, if these financial problems are completely self-inflicted, or if there is a role for contagion emanating from Greece.

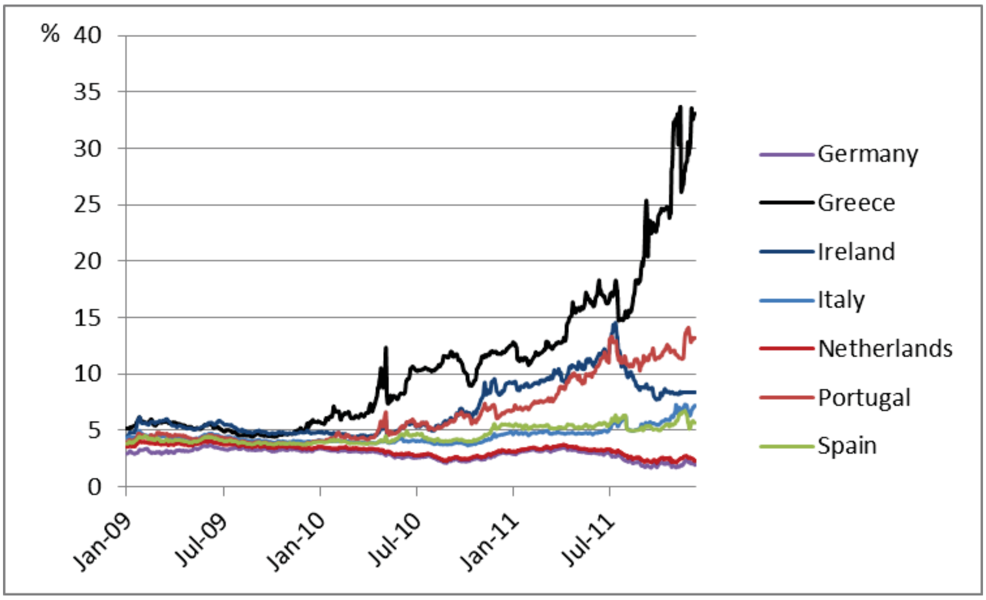
DCC models are estimated for government bond yields of selected euro area countries for the period from January 2009 until December 2011 in order to assess if contagion is at work during the European debt crisis. Our findings suggest that there is contagion at work within the euro area. Specifically, we detect contagion during the May 2010 period. In addition, we find that negative Greek rating announcements lead to contagious effects to other euro area sovereign debt.

3.2 Introduction

Since the end of 2009, the euro area faces a severe sovereign debt crisis, generally known as the European debt crisis. Rising government deficits and debt levels triggered rating agencies to downgrade several European countries' sovereign debt. With bond yields of ailing countries increasing considerably, refinancing conditions worsened dramatically. A broad loss of confidence in financial markets was created.

Although the European debt crisis has its starting point in the comparatively small Greek economy - and in particular in the Greek government's financing problem - it has moved on to endanger some of the largest European economies, if not the entire euro area. Figure 3.1 shows that since the beginning of the crisis, yields of several euro area countries have increased substantially as well.

Figure 3.1: Government bond yield development



Percentage 10-year benchmark government bond yield development during the European debt crisis for Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain.

Financial market participants are led by different aspects when it comes to making investment decisions. One driving factor influencing the markets' assessment of the riskiness of sovereign debt can be contagion. Chapter 3 focuses on the question whether these government bond yield movements are to some extent caused by contagion within the euro area.

This contagion analysis is first and foremost important for understanding the causes of the crisis. Second, it is crucial for designing appropriate policy responses. If contagion is considered of minor importance in the development of the crisis, then countries most importantly need to implement structural reforms to enhance competitiveness and to restore fiscal consolidation. If, however, contagion is found to be a significant contributor to the crisis, then joint European policy responses aiming at insulating the rest of the euro area from the by-now infected countries are called for.

Important for any study of contagion, is the right definition of the concept. Somewhat unfortunately, there are many different but related ways to define contagion, each depending on the specific question at hand. Furthermore, there is also a similar amount of different empirical approaches used to identify contagion. A nice summary of both definitions and approaches is provided in Forbes (2012).[12]

The author shows, that integration and in accordance therewith also the threat of contagion has increased dramatically in the course of time. While this development is true for the global picture, evidence is even stronger for the euro area. Moreover, it is demonstrated that a country's vulnerability to contagion depends on four important channels: Trade exposure, banking leverage, portfolio investment and macroeconomic fundamentals or the sentiment about that fundamentals. For her contagion analysis, the author initially gathers and evaluates various working definitions and identification methodologies common to the literature.

In the first part of our study, we define that contagion is at work if financial problems of one country in any way affect other countries negatively. The financial situation of the infected country is assessed worse than it would be without the existence of the infecting country. This notion of contagion closely follows the preferred definition used in Forbes (2012), which calls for contagious effects once negative events of any kind in a foreign country spread to the home country and by no means can the home government prevent or influence the original foreign event. This general concept allows for contagion caused by interrelations of fundamentals across countries as well as contagion due to unjustified – or non-fundamental – extrapolation of market belief.

[12] For a more detailed overview of theoretical definitions and empirical measures used in contagion analysis refer to Pericoli and Sbracia (2003) or Dungey et al. (2010).

When it comes to contagion identification methodologies, Forbes (2012) discusses the advantages and disadvantages of the five most important approaches, which are probability analysis, VAR models, extreme value approach, cross country correlations and GARCH models. In our analysis, we apply a combination of the last two methods. In order to empirically implement the identification of contagion, we estimate a special version of MGARCH models, the DCC model of Engle (2002) and Engle and Sheppard (2001).[13]

The DCC model specifically aims at estimating time-varying, dynamic correlations between different time series. This allows us to empirically evaluate, how the co-movements of government bond yields changed during the European debt crisis and if that change in co-movements provides evidence for the existence of contagious effects. We consider combining a correlation based identification strategy with this MGARCH model as highly adequate for contagion analysis. Drawbacks of conventional correlation based concepts can be circumvented, as is discussed later together with the correlation based contagion literature.

When it comes to defining contagion, however, the literature often deviates from the general contagion concept used in Forbes (2012) and in the first part of our analysis. A differentiation between fundamental linkages, which connect countries in good and bad times, and non-fundamental linkages, which only exist during or after a crisis, is considered. If there is a crisis in which one country exemplarily infects another because of fundamental cross country banking interactions, interdependence is concluded instead of contagion. The argument behind this result is that the banking connection existed also before the crisis. Things change, however, if an infection occurs because of purely sentiment driven liquidity withdrawal, as such non-fundamentally justified investor behavior did only begin with the crisis.

The DCC results only allow for the identification of contagion as the generally defined concept in the first part of our analysis. A comparison between contagion caused by the spread of crises through fundamental linkages - e.g. trade or banking interdependences - and non-fundamental contagion is not possible. The second part of our study focuses on the identification of the specific cause of contagion. We apply a less general definition of

[13] The DCC model is already discussed in Chapter 2. For an explanation of the DCC model refer to Appendix A in Subsection 2.8.1.

contagion and based on the initial estimation results from the DCC model, we specifically analyze whether there is a role for non-fundamentally driven contagion in the crisis.

To this end we follow the work of Kaminsky et al. (2003). We deviate from the general contagion concept of the first part and instead define contagion more restrictively as the fast and furious reaction of financial market prices to events that are or seem unrelated to the fundamental environment. In order to evaluate if the contagious effects identified in the first part of our work are to some extent due to such kind of non-fundamental market sentiment, we study the behavior of the estimated time-varying correlations around Greek sovereign rating downgrades.

Under the plausible assumption that Greek rating downgrades do not indicate changes in fundamentals for the whole euro area, we study if the correlations of other European countries' government bond yields vis-à-vis the Greek yield change significantly. If Greek rating events do have a significant impact on other countries' bond yield developments, then there is non-fundamentally justified extrapolation of bad investor sentiment from Greece to the euro area. This provides evidence for sentiment driven contagion in accordance with the Kaminsky et al. (2003) fast and furious definition.

The remaining chapter is organized as follows: Subsection 3.3 reviews related literature. Subsection 3.4 describes our dataset and some initial results based on realized correlations. Input data is modified according to principal component analysis in order to address the well documented common global factor problematic of empirical contagion analysis. Subsection 3.5 describes the results of the first part of this chapter. The general contagion analysis is presented. All results are interpreted against the background of the European debt crisis. Subsection 3.6 covers the results of the second part of this chapter. The analysis is extended in order to study if announcements of Greek rating downgrades have non-fundamental contagious effects on other countries' yields. Subsection 3.7 concludes.

3.3 Literature

Throughout Chapter 3, the contagion analysis is based on the correlation development of government bond yields. The main results indicate that there is contagion at work during the

European debt crisis. In the second part, we additionally provide evidence for non-fundamentally driven contagion. The correlation based identification strategy for contagion is not new to the literature. Also contagion in the context of the European debt crisis is frequently discussed. Important contributions regarding our preferred identification methodology and contagion in the euro area are therefore summarized in the following.

Using a correlation based identification methodology is both supported by stylized facts on contagion transmission mechanisms - as summarized in Corsetti et al. (2011) - and by the long history of further and further improved correlation related contagion literature. As common practice in correlation based contagion studies, a sudden increase in cross country asset correlation, which quickly reverts back afterwards, is regarded as an indication for contagion. The reasoning behind this identification strategy can be summarized as follows:

As long as correlations are calculated adequately, an increase in correlations between financial assets is evidence for contagion due to two different channels or a combination thereof. First, contagion can be driven by fundamentals. The fall of one asset's price has strong negative effects on another asset, i.e. bad development of one asset really implies bad development for the other asset. If there is such a fundamental connection, then asset prices tend to plummet simultaneously and the correlation rises.

Second, contagion can be driven by non-fundamental factors such as investor sentiment. Bad information on one financial asset serves as indicator that equally bad information also represents another asset. Even if that is not true for the fundamentals of the two assets, investors' panic nevertheless drives a similar plunge of both asset prices. The correlation between the assets therefore rises as well.

Finally, as argued in Forbes and Rigobon (2002), a permanently high correlation level is not considered as evidence for contagion but for interdependence. Interactions between two different assets can be existent in crisis and in normal times. If those connections, however, lead to higher co-movements only in crisis times, contagion seems to be at work. Therefore, not a permanently high level of correlations, but only a sudden surge in correlations which quickly reverts back to its normal average allows for the identification of contagion.

Early empirical contagion analysis building on correlation estimates is done by King and Wadhwani (1990). The authors compare static non-conditional correlation estimates between stock markets for sub-periods around the crash of October 1987. Relying on this basic framework, different extensions were developed in order to improve correlation estimates for a more suitable contagion analysis.

Non-conditional correlation estimates can lead to upwardly biased contagion identification. Empirical evidence shows that volatility generally increases during crisis periods. Non-conditional correlation estimates grow automatically with rising volatility. This increased correlation is thus not necessarily caused by contagion, but can also have a purely statistical reason. Forbes and Rigobon (2002) therefore rely on a more sophisticated, heteroskedasticity adjusted correlation measure, in order to allow for unbiased contagion testing. Further thoughts on this conditional heteroskedasticity problem and its influence on correlation estimates are discussed in Dungey and Zhumabekova (2001) or Corsetti et al. (2005, 2011). General consideration on statistical prerequisites for the comparison of correlation estimates is provided by Boyer et al. (1997) and Loretan and English (2000).

Caporale et al. (2005) address a different problem and advance the contagion analysis by endogenizing the break points between normal and contagious periods. Earlier contagion studies assumed contagious and non-contagious periods and calculated static correlation estimates for the two exogenously given time spans. Different timing of the two static periods can, however, account for different conclusions of the contagion analysis. With endogenized break points, the static analysis becomes dynamic and the problem is resolved.

Our empirical method is most closely related to Chiang et al. (2007). The authors estimate a DCC model and identify an important role for contagion during the Asian crisis in 1997. Co-movements derived from DCC models solve the major problems associated with correlation based contagion analysis. As demonstrated in equation (A.2.5) of Appendix A in Subsection 2.8.1, conditional correlation estimates are based on volatility adjusted GARCH residuals. Potential bias caused by conditional heteroskedasticity is therefore corrected.

Also, an exogenous setting of contagious and non-contagious periods is not necessary. In static analyses, a comparison of correlation estimates for earlier defined sub-periods is carried out. In the DCC model, one correlation estimate for each single day of the observed time series is derived. Comparison of correlation estimates on a daily level becomes possible and thus sudden increases in co-movements can be easily recognized. The static correlation development is rendered dynamic.

In our analysis, we provide evidence for contagion during the European debt crisis. To the best of our knowledge, there is not yet any correlation based study on government bond yields during this specific crisis. Yet there is literature which is in accordance with our results. A study directly addressing the question, if contagion is at work during the European debt crisis is done by Arghyrou and Kontonikas (2011). Building on the theoretical model of Arghyrou and Tsoukalas (2011), the authors confirm that EMU countries suffered from contagion originating in Greece. Especially Ireland, Portugal and Spain are strongly affected by the Greek turmoil.

In the second part of our analysis, we use rating data to show that there is also a role for non-fundamental contagion. Arezki et al. (2011) investigate, if there are spillover effects caused by rating news in Europe. The analysis is based on data on sovereign CDS spreads, stock market indices and indices for banking and insurance. The authors provide evidence that rating announcements in some euro area country did significantly affect other euro area countries during 2007 and 2010.

Another study by Afonso et al. (2012) supports the findings that negative ratings trigger spillover effects within the EU. In a different study, De Santis (2012) reveals that crisis countries are not primarily evaluated according to their fundamentals, but that contagious effects caused by rating downgrades play an important role in the euro area. Ratings driven contagion especially hits countries with weak fundamentals. Rating cuts in Greece, Ireland or Portugal affect the yield behavior among the other euro area countries, with Greek ratings by far exerting the strongest impact.

A recent study by the ECB (2012) carries out related DCC model estimations, but addresses the international equity markets as compared to the bond market analysis of our study. A nice summary of different contagion mechanisms and the role of the ECB during the European debt crisis can be found in Bindseil and Modery (2011).

3.4 Data

3.4.1 Yield data and realized correlation analysis

Our contagion analysis is based on 10-year benchmark government bond yields for a sample of seven euro area countries: Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. We use business daily data for a time span ranging from 01.01.2009 until 15.12.2011 giving 771 observations. Figure 3.1 already provided an overview of the yield development of those countries within this time frame. Table 3.1 presents a descriptive overview of the data.

Table 3.1: Descriptive statistics of government bond yields

Yield series	**Average**	**Standard deviation**	**Maximum**	**Minimum**
Germany	2.913	0.463	3.696	1.690
			(11.06.2009)	*(22.09.2011)*
Greece	10.718	6.559	33.654	4.423
			(17.11.2011)	*(08.10.2009)*
Ireland	6.884	2.326	14.552	4.365
			(18.07.2011)	*(10.03.2010)*
Italy	4.534	0.711	7.311	3.663
			(25.11.2011)	*(11.10.2010)*
Netherlands	3.247	0.484	4.134	2.121
			(26.01.2009)	*(04.10.2011)*
Portugal	6.539	2.866	14.121	3.714
			(02.12.2011)	*(01.12.2009)*
Spain	4.581	0.718	6.752	3.722
			(25.11.2011)	*(01.12.2009)*

10-year benchmark government bond yields during the European debt crisis for Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain.

The average bond yield is highest for Greece and around 3.5 times higher than the interest charged from Germany. While the maximum yield for the Netherlands and Germany is realized in the first half of 2009, the maximum yields for the other five countries are concentrated in the second half of 2011. Countries facing higher average bond yields also tend to have higher yield standard deviations, backing the fact that volatilities increase during crisis periods.

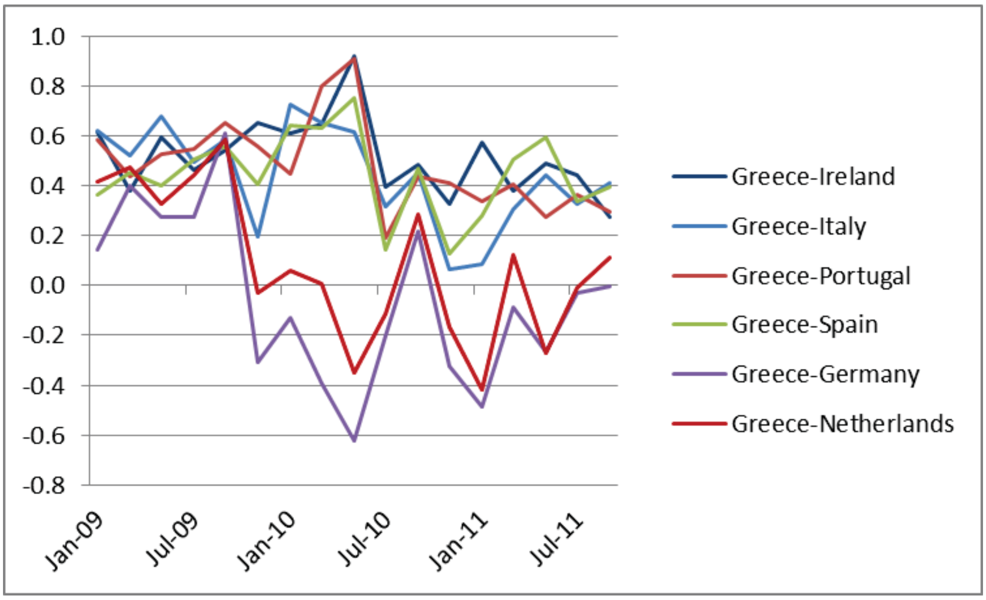
Greece was the first country experiencing refinancing problems and was also the first that had to ask for financial support. At the same time, the Greek economy unfortunately suffers from arguably sizeable political as well as economic instability. Hence if there is contagion within the euro area, it seems plausible to take Greece as a starting point from which contagion might have spread to other countries or markets. We consequently calculate the correlation coefficients of all other countries' bond yields vis-à-vis the Greek bond yield.

During the European debt crisis, the euro area periphery stands for a higher probability of economic distress, as shown by problems with budgetary discipline and competitiveness. At that time, Ireland, Italy, Portugal and Spain seemed to be particularly vulnerable to contagion and can rather safely be called crisis countries. If there are contagious effects originating in Greece and spreading over to other economies, it is most likely to identify them for some of these four countries.

The euro area core countries, in particular Germany, are regarded as safe havens for investment. Though negative effects can also spill over to countries which are regarded as safe, the likelihood of such a development is by far smaller as compared to the European periphery. We therefore use Germany and the Netherlands as control countries for which we expect that contagion identification is less likely. Evidence for contagion should either be absent or comparably small.

As preliminary analysis of the correlation structure of the bond yields, we calculate so-called realized correlations. Realized correlations are a simple way to present historical correlations by exploiting the high-frequency nature of our data. Figure 3.2 shows realized correlations calculated on a bimonthly basis from our business daily yield data.

Figure 3.2: Realized correlations



Realized correlation development of 10-year benchmark government bond yields between Greece vis-à-vis Ireland, Italy, Portugal, Spain, Germany and the Netherlands during the European debt crisis. Correlations are calculated on a bimonthly basis.

There seem to be different correlation dynamics amongst the various country pairs. In particular, realized correlations increase in the first half of 2010 for Greek-Irish, Greek-Portuguese, Greek-Spanish and to a lesser extent Greek-Italian bond yields, whilst at the same time Greek-German and Greek-Dutch yield correlations decreased rapidly. Referring to the contagion literature, we take this observation as a preliminary indication that contagion might indeed be at work in the European debt crisis. We investigate this first impression in greater detail and with statistical back-up in the Subsection 3.5 through means of the DCC model.

3.4.2 Principal component analysis

The yield data presented above is not yet suitable for the contagion analysis. Data modification according to the global factor problem in contagion analyses, as addressed by Dungey et al. (2007) is crucial. The authors recognize that every time series evaluated in an empirical contagion analysis is to some extent driven by a so-called global factor. A change in the global factor can simultaneously influence every time series and in our methodology also the correlation between those.

Basically, the correlation based contagion literature identifies contagion according to increases in co-movements between two countries' assets. If there is, however, a global factor equally affecting both countries at the same point in time, the correlation between the countries' financial assets naturally increases. A sudden increase in correlations can consequently either be caused by contagion or by a change in the global factor.[14] An ex post distinction between the two potential effects is difficult.

There are two major ways of an ex ante adjustment for the global factor. The global factor generally consists of an unknown number of different components. The first approach addressing the global factor question is controlling for each single of these components individually. In their DCC analysis on the Asian crisis in 1997, Chiang et al. (2007) apply lagged US stock returns as important drivers of Asian countries' stock returns to control for the global factor. Different other variables have been used as well, like for example in Forbes (2012), Eichengreen et al. (1996) or Podlich and Wedow (2011).

However, following this procedure and arranging a set of variables in order to proxy the global factor generates problems. First, directly controlling for each and every relevant variable seems unfeasible, as one can never be sure to rely on the correct and even more problematic on the complete factor set. Second, because of our use of daily data and a rather short sample period, we believe our analysis is reasonably immune to the rather discrete nature of changes in fiscal stance and current accounts that occur usually on a monthly or quarterly basis.

The second approach circumvents that drawback by extracting the global factor set as a whole by using principal component analysis. Favero et al. (2010) conduct principal component analysis to European yield differentials and find a first principal component explaining more than 90% of total variation in bond yield movements. The authors consider this first principal component as the common international component of European yield development. Ehrmann et al. (2011) also apply principal component analysis and identify one factor that nearly exclusively represents European bond yield movements.

[14] Besides other examples, the common monetary policy for the euro area represents a part of the global factor in our raw data. Loosening monetary policy could potentially simultaneously boost every analyzed economy and therefore lead to higher co-movements of assets even in the absence of contagion.

We follow this second approach and consider the first principal component as the common global factor jointly driving euro area yield data. This methodology lacks the opportunity to name the elements of the global factor, but rather safely allows the adjustment for the statistically most important common driver of the time series. Once this global factor is removed from the bond yield data, it is possible to investigate, if there is a contagious factor which jointly drives the modified European yield data.

The principal component analysis is performed for only six countries excluding Greece. This exclusion of Greece is necessary, as we regard Greece as the origin of the contagion crisis. If there is contagion spreading from Greece, then Greece drives the other countries' bond yields jointly. Inclusion in the principal component analysis would result in filtering precisely the contagious effects which we want to find. As argued in de Bandt and Hartmann (2002), a shock to a smaller country - in our study Greece - can evolve into a bigger shock infecting other countries, in here the contagion in which we are interested. Including Greece in the principal component analysis would remove exactly that contagion from the data.

Table 3.2 shows that there is a common international factor jointly driving the bond yields of European countries. In total, six principal components are calculated. The eigenvalue describes the proportion of joint variation in the time series which is explained by the single principal components. The first principal component with an eigenvalue of 13.497 captures 89% of the joint variation within the time series. The first two principal components are responsible for 97% of the joint variation.

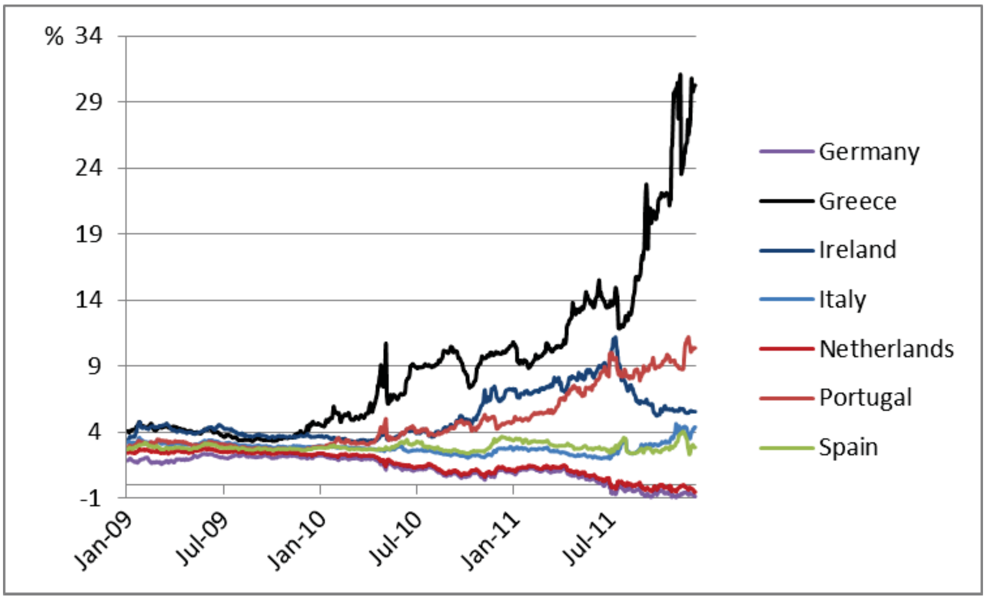
Table 3.2: Principal component analysis

Component	**1**	**2**	**3**	**4**	**5**	**6**
Eigenvalue	13.497	1.188	0.264	0.110	0.030	0.006
Proportion of variance	89%	8%	2%	1%	0%	0%
Cumulative	89%	97%	99%	100%	100%	100%

Proportion of variance explained by each principal component and cumulative proportion of variance explained by principal components 1,…,6. Exemplarily, the first principal component explains 89% of the joint variance in the yield series. The second principal component accounts for 8% of the variance. Cumulative, the first and the second principal component explain 97% of total variation.

By filtering the first principal component, we adjust the original time series for a factor which explains 89% of the joint variation. This percentage is reasonably high to conclude that the global factor, i.e. the most important joint driver of all original yield series, is approximated and extracted by the first principal component. The modified data fulfills all theoretical prerequisites for the contagion analysis. If changes in correlations can still be identified for the adjusted yield series, it can be ruled out that those co-movements are solely driven by a change in the global factor. Figure 3.3 shows the adjusted bond yield development.

Figure 3.3: Modified government bond yield development



Percentage 10-year benchmark government bond yield development during the European debt crisis, adjusted for the first principal component, for Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain.

3.5 Contagion analysis

According to Engle (2002) and Engle and Sheppard (2001), we estimate dynamic conditional correlation series of 10-year benchmark government bond yields between Greece and the other six countries of the sample. Greece was the first country witnessing the problems of the sovereign debt crisis and therefore represents the origin of our contagion analysis.

The sample of countries allows us to investigate, if there are differences between periphery and core countries. Following the literature we consider a sudden surge of several countries' bond yield correlations at the same point in time as evidence for contagion. Due to the principal component analysis, we can rule out common global factors causing such an increase in yield correlations.

3.5.1 Different phases of the crisis

Figure 3.4 shows the development of daily dynamic correlation estimates. For clarity reasons, the figure is divided in two subplots. The upper subplot depicts correlations between Greece vis-à-vis Ireland, Portugal and Spain, the lower subplot between Greece vis-à-vis Italy, Germany and the Netherlands. Additionally, the days of the first and second rescue package for Greece, the agreement on the EFSF and the first haircut of private debt holders are indicated by vertical lines.[15]

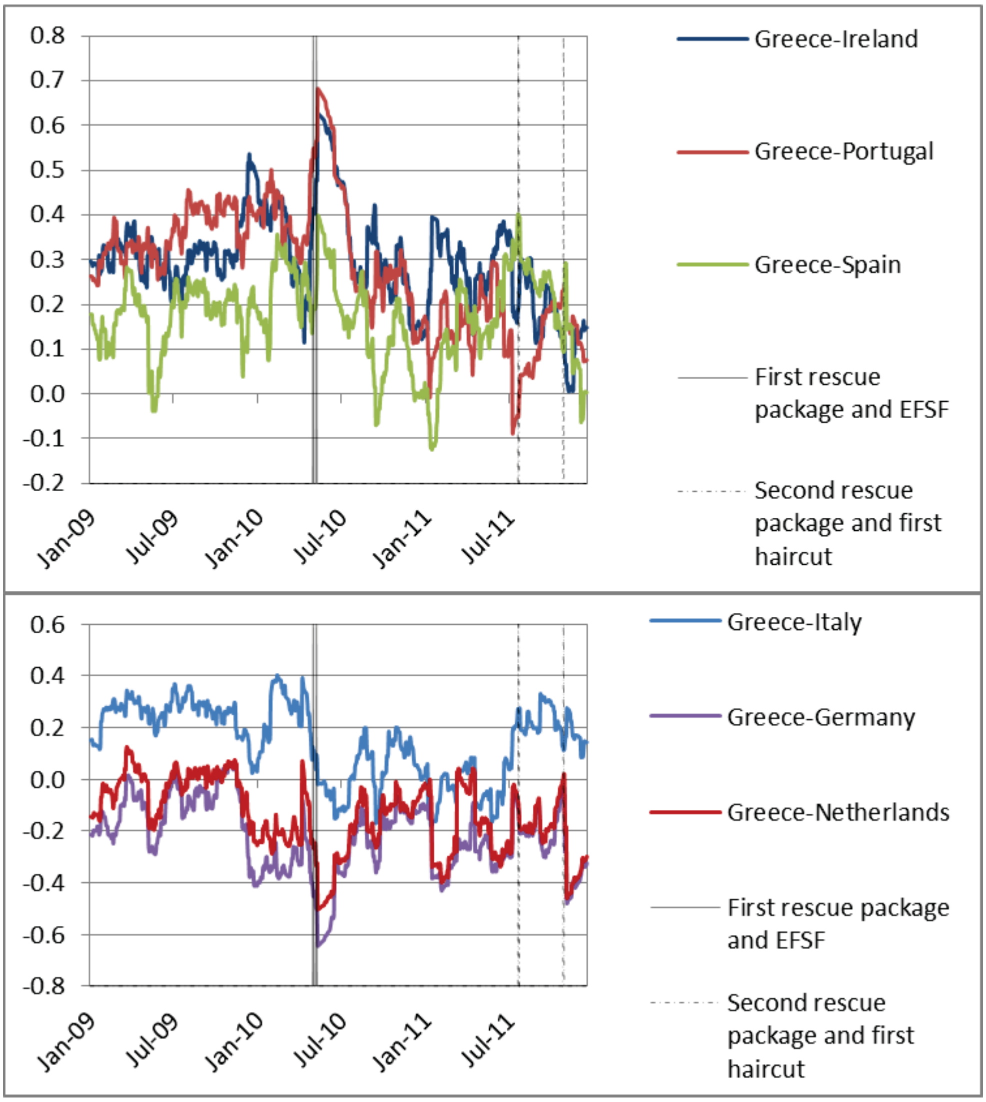
The overall estimation results seem plausible from visual inspection. The correlation estimates between Greek bond yields and the other four financially troubled countries Ireland, Italy, Portugal and Spain are on average positive. The average correlation is highest between Greece and Ireland followed by the correlation with Portugal. That might be due to the closest similarities when it comes to size, economic situation and financial problems of these three countries. The correlation between Greece vis-à-vis Germany and the Netherlands is on average negative, with Germany's yield movements being most asynchronous of the whole sample. This result seems also plausible due to the better financial and fiscal situation of the two core countries.

The correlation figures for the four financially disordered countries initially increase, while the financially sound countries are affected in the exactly reversed way. This leads to our conclusion that contagion seems to be at work during the European debt crisis. The evolvement of the correlation dynamics since 2009 is now interpreted in more detail with regard to the political and economic development in the euro area. As our analysis examines the question if there are contagious tendencies originating in Greece and spreading from there to other euro area economies, we subsequently mainly summarize important Greek events. Based on those events we draw conclusions for the Greek bond yield correlation vis-à-vis the other countries in our sample. Between the beginning of 2009 and late 2011, events and

[15] For the DCC model specification of the contagion analysis refer to Table A.3.1 of Appendix A in Subsection 3.8.1.

information regarding the Greek economy came thick and fast. A yearly breakdown of the most important aspects is provided in the next three subsections.

Figure 3.4: Contagion analysis



Dynamic conditional correlation estimates of 10-year benchmark government bond yields between Greece vis-à-vis Ireland, Portugal and Spain (upper subplot) and Italy, Germany and the Netherlands (lower subplot) during the European debt crisis. Vertical lines indicate the days of the first Greek rescue package and the agreement on EFSF (verticals on the left) and the second Greek rescue package and the first Greek haircut (verticals on the right).

3.5.1.1 Beginning of the crisis in fall 2009

On 04.10.2009, George Papandreou's PASOK wins the Greek general elections. On 20.10.2009 the new government has to officially revise upward the budget deficit from the projected 6% to 12% or 13% of GNP. By the beginning of the next year, the yield spread between the Greek 10-year benchmark government bond and its German counterpart increases over 3% for the first time since January 2001. Table 3.3 provides an overview of important Greece related events of 2009.

Table 3.3: Important Greece related events of 2009

2009	
Date	**Event**
04.10.2009	Social democrats (PASOK) win general elections
06.10.2009	Prime minister George Papandreou inaugurated
20.10.2009	2009's budget deficit of 6% revised to around 12% or 13% of GNP

The relatively uneventful time before October 2009 is adequately represented by correlation dynamics without any major trend changes. Beginning with the revelation of the budgetary problems and the subsequent events things, however, start to change. The correlations between Greece and Ireland, Italy, Portugal and Spain increase while the correlations between Greece and Germany and the Netherlands display opposite dynamics.

Events in Greece seem to trigger a higher correlation between the sovereign debt assets of the periphery. There is – at this stage – still no comparable worsening of fundamental information in those periphery countries, thus indicating a first sign for contagion. In accordance with ex ante expectations, Greece seems to infect the periphery countries, while the core countries are not drawn into contagion.

3.5.1.2 The crisis intensifies in 2010

After a first austerity package had failed to bring the Greek budget back on track, on 25.03.2010 the EU countries and the IMF declare their willingness to provide financial support. One month later, the Greek government decides to take that very step and the final negotiations for a Greek bailout begin. In early May, the negotiations concerning the financial support of Greece come to a conclusion. On 02.05.2010, the euro area countries, the ECB and the IMF agree on a first rescue package for Greece. The financial support amounts to 110 billion euro in exchange for a second austerity package. The Greek government agrees to the required conditions two days later.

Besides the rescue package consisting of bilateral credit provision, the implementation of the preliminary EFSF is agreed a week later on 10.05.2010. This facility combines lending capacities guaranteed by the euro area countries (440 billion euro), the European Commission (60 billion euro) and the IMF (250 billion euro). The total of 750 billion euro is available for the support of financially distressed euro area countries.

Monetary policy measures provide complementary support for the intervention on governmental levels. With effect from 03.05.2010, the ECB accepts all Greek issued or guaranteed debt titles as collateral for central bank lending. By means of this decision, the refinancing conditions especially for Greek banks are fostered. On 10.05.2010, the ECB additionally initiates the Securities Markets Program. The program starts the central bank’s intervention on sovereign and private securities markets with the purpose to guarantee the functioning of the transmission mechanism of monetary policy in light of dysfunctional financial markets. Table 3.4 provides the overview of events in 2010.

Table 3.4: Important Greece related events of 2010

2010	
Date	**Event**
11.02.2010	Special EU-summit: First Greek austerity package
25.03.2010	Euro area countries and IMF announce preparedness for financial support for Greece
23.04.2010	Greek government officially asks for financial support
02.05.2010	EU, ECB and IMF agree on first rescue package for Greece amounting to 110 bn €
02.05.2010	Second Greek austerity package
03.05.2010	ECB accepts Greek government bonds or bonds guaranteed by Greece as collateral without discount
10.05.2010	European heads of government and state agree on EFSF amounting to 750 bn €
10.05.2010	ECB initiates Securities Markets Program
07.06.2010	EFSF established
17.12.2010	EU leaders approve ESM

By the end of March 2010 and at the same time of the worsening information about a potential need for external support for Greece, our correlations with the periphery countries show a steep increase. Subsequently, the correlations of Greek and Irish, Portuguese, Spanish and Italian bonds continue to rise to levels not seen before. These correlation dynamics strongly suggest contagion at work, which is either channeled through fundamental interconnections mainly in the banking system or through investors' extrapolation of bad information.

More specifically these two different channels can be explained as follows:

1. On the one hand, contagion can be driven by worsening fundamentals across the euro area. The threat of Greek insolvency has fundamental drawbacks on other countries. Banks invested in Greek government bonds are directly hit by a Greek default. National governments have no choice but supporting their own banks. The looming banking collapse is therefore transmitted to the countries.

   The fear of a further deterioration of the budgets of already distressed periphery countries triggers yield increases in the periphery. Financial markets charge higher risk premiums because of the fundamental connection between the Greek default probability and a thereof triggered cascade of other countries' default. This leads to an increase in yield correlations between Greece and other financially unstable countries. This mechanism can be described as contagion caused by fundamentals. Actual changes in default probabilities are the prerequisite of a higher co-movement of sovereign debt prices.

2. On the other hand, Greek problems might also spread to other countries even though they are not related in a fundamental sense. Bad information about the Greek fiscal condition increases yields on Greek government bonds. Financial markets extrapolate this worsened Greek outlook on to other countries of the periphery. It is generally perceived in financial markets that these other countries also have comparable budgetary weaknesses. Fear and panic then quickly emerge in the markets.

> Markets in a sense extrapolate the Greek problem to the other countries through worsened sentiments. As a consequence, other countries' yields tend to increase at the same time as Greek yields increase. Correlations again rise. The whole mechanism can be described as contagion caused by investor perception and herding. In other words, it is a non-fundamentally driven explanation of contagion.

In both cases, the freed up capital or liquidity rushes into less risky investment opportunities and finds a safe haven in the core European countries. Hence, yields of Germany and the Netherlands behave in the very opposite direction and correlations shrink accordingly.

In actual fact a combination of the two potential explanations for contagion seems most likely to have happened. However, the aim of the first part of this analysis is not to address the question of separating the two potential contagious mechanisms, but to provide evidence that there is contagion at all, no matter how it is channeled. For either interpretation we take the dramatic increase of correlations between Greece and the periphery countries as strong evidence for contagion during the European debt crisis.

The set of countries being affected by contagious effects seems plausible. Though not being in the same predicament as Greece, also Ireland, Italy, Portugal and Spain are in financial trouble as well. Therefore it seems reasonable to suppose that these countries suffer from contagion. The more solid economies of Germany and the Netherlands remain unaffected from contagion. Actually, they even experience the exact opposite, as they act like safe havens in the troubled euro area.

The first rescue package and the EFSF as well as the measures taken by the ECB were clearly aimed to calm the Greek problem from spreading to other countries. In May 2010, the correlations quickly shrink again. This change in the dynamics starts roughly around the first week of May, i.e. shortly before or after the agreement of those measures. This new development further strengthens the contagion evidence, again based on the same two lines of argumentation:

1. If there is contagion caused by fundamentals, the taken measures address the problem. Once there is a bailout facility for distressed countries, fundamental problems may still spread from the banking sector to the countries. However, sufficient funds to support infected countries are now directly available. The default risk of other euro area countries consequently drops and yields can disconnect from Greek sovereign debt. Additionally, because of the rescue package for Greece and the eased refinancing conditions of the ECB, a spreading of fundamental problems from Greece to other countries becomes less likely.

2. If there is contagion caused by bad investor sentiment, the problem is again mitigated with help of the same measures. Should there really be other countries in similar bad financial conditions as Greece, then there is a bailout facility to which every single euro area country has immediate access. No long lasting further bilateral negotiations are required in the case of another country asking for financial support. Thus the expectations of default of other euro area countries can be reconsidered. Acute panic is calmed down due to the size and working mechanism of the construct. Financial markets start to analyze other countries again more independently from the Greek situation. Yield movements can disconnect from Greek yields and correlations decrease quickly.

Both in the cases of sentiment or fundamentally driven contagion, the rescue measures function as a firewall. Periphery countries are safeguarded against either real or perceived increased default risks. The threat of contagion is contained and therefore the correlations between Greece and the remaining countries in the sample move back to less extreme or even normal levels.

Our DCC results seem to confirm the initial success of the contagion containing measures. While the correlations start to shrink to their usual average levels after the decision for the first rescue package, the EFSF and the ECB measures, they also remain at these levels the time afterwards. In the second half of 2010 and the first half of 2011 the consolidation plans stay roughly on track. Though there are some minor complaints by the Troika reviewing

Greece, all financial support tranches are paid out according to plan and without the danger of potential suspension.

3.5.1.3 Ongoing crisis in 2011

In May 2011, the Greek rescue plan starts to struggle with major problems. Against a strong political opposition, a third austerity package has to be accepted by the Greek government on 29.06.2011. As sufficient improvements in Greece's fiscal stance are not achieved, the euro area has to implement a second rescue program for Greece on 21.07.2011. This second program consists of EFSF and IMF payments of 109 billion euro over the next three years and a voluntary participation of private banks amounting to 37 billion euro. On 27.10.2011, a new long term strategy in combination with a haircut of 50% of private holders of Greek debt is passed by euro area countries. Subsequently, prime minister Papandreou steps down and is replaced by a transitional government under prime minister Lucas Papademos. Table 3.5 shows the overview of events of 2011.

Table 3.5: Important Greece related events of 2011

2011	
Date	**Event**
11.03.2011	EU introduces Pact for the euro for more competitiveness and political integration
27.05.2011	Greek parliament votes against new austerity measures
29.06.2011	Third Greek austerity package despite strong resistance
21.07.2011	Euro area and IMF agree on second rescue package for Greece amounting to 109 bn € plus 37 bn € contributed by private banks
02.09.2011	Troika stops review of Greek consolidation progress and leaves Athens
21.09.2011	Greek government announces necessity for further austerity measures
11.10.2011	Troika concludes review of Greek consolidation progress
27.10.2011	Euro area presents long term strategy for Greece, haircut of private debt holders of 50%
01.11.2011	Prime minister Papandreou announces referendum for further acceptance of austerity measures
03.11.2011	Prime minister Papandreou refrains from referendum and steps down because of threatened suspension of rescue payments
04.11.2011	Greek installs new transitional government
11.11.2011	Prime minister Lukas Papademos inaugurated
09.12.2011	European fiscal compact agreed, budgets obliged to be balanced

By May 2011, the Greek government starts to question the conditions for further support. At the same time, the euro area governments consider more austerity and rescue packages inevitable. From then on, the implementation of new consolidation measures, threats from the Greek government not to adhere to it and threats from the Troika to suspend payments regularly take turns.

At that point in time, correlations between Greece and the periphery again begin to rise and now especially the correlations with Italy and Spain reach new heights. Similar to the situation in May 2010, the same two lines of argumentation can be used to explain that development. Bond yields of Italy and Spain behave in a similar way as the Greek yields because either investors fear fundamental spillovers from the interconnected banking sectors or because bad sentiment is extrapolated. This time the two bigger European economies display the stronger negative effects. This might be due to the uncertainty whether the already implemented bailout and rescue mechanisms are high enough to also protect the large economies of Italy and Spain.

Also at that point in time, however, a second set of measures serves as successful remedy which manages to reverse the bond yield behavior again. With the implementation of the second rescue package and the first haircut for Greece, the contagious tendencies can be stopped. By means of the two measures, a smaller likelihood of fundamental contagion and a likely improvement of investor sentiment can be reached. Consequently, the bond yield development again disconnects from the Greek development. As shown in Figure 3.4, correlations initially increase again before reverting back around the time of the new measures. As argued for May 2010, the actions taken contain contagion efficiently in 2011.

Summarizing, we conclude that the spreading refinancing problems within the euro area are to some extent aggravated by contagion. Affected countries are in a worse condition compared to a hypothetical situation without the Greek problems. This knowledge is important for the choice of policy intervention. As argued by Forbes (2012) or Forbes and Rigobon (2001), in contagious times different policy reactions are adequate as compared to times without contagion. The implementation and evaluation of measures therefore crucially depends on the identification of contagion.

3.5.2 Further contagion evidence

Based on the dynamic conditional correlations, the strongest contagious pressures are identified in summer 2010. Especially in the period around the decision for the first measures aimed at containing contagion, periphery countries seem heavily affected by the Greek circumstances. In order to further confirm the contagion evidence statistically, a test strategy similar to Chiang et al. (2007) is applied.

We estimate a dummy regression in order to test the significance of the increases in co-movements. For each country pair, we implement the estimated dynamic conditional correlations from Subsection 3.5.1 into AR(1) models, which we extend by a dummy variable for May 2010. We assume that the month May is most suitably capturing the contagious pressure of summer 2010 and we therefore regress the dynamic conditional correlations on the May-2010 dummy as well as on a lagged dependent variable to remove any remaining autocorrelation in the residuals. The estimation equation is given in (3.1).

$$\rho_t = \varphi + \kappa\rho_{t-1} + \eta D_{May-2010,t} + u_t \tag{3.1}$$

In equation (3.1), ρ_t represents the estimated dynamic correlations of the DCC model. $D_{May-2010,t}$ is a dummy variable accounting for the presumably contagious period of May 2010. It takes a value of one between 01.05.2010 and 31.05.2010 and a value of zero otherwise. Finally, u_t is the error term and φ, κ and η are the parameters to be estimated.

If for any correlation series the parameter estimate η of the dummy variable is significantly greater than zero, the co-movements are indeed higher during that specific period. The hypothesis is tested by using standard Wald t-tests. Table 3.6 shows parameter estimates and test results. The upper row numbers refer to the parameter estimates for the autoregressive term κ and for the dummy parameter estimate η of equation (3.1). The lower row numbers in parentheses refer to t-statistics of the conducted Wald t-tests.

As expectable, all correlation series display a highly significant autoregressive term, representing the persistency of the co-movement process. The dummy parameters of Ireland, Portugal and Spain are significantly positive and thus confirm a contagious period in May

2010. The bond yield correlation between Greece and these three countries is significantly higher during May 2010 as compared to the remaining observation period. Our contagion hypothesis can thus be maintained. For Germany and the Netherlands, correlations are significantly lower during the same period and no contagion is identified. For Italy, no significant effect is found.

Table 3.6: Contagion dummy regression estimates

Correlation series	**AR 1**	**May 2010**
Greece-Ireland	0.969***	0.017***
	(348.592)	*(5.092)*
Greece-Italy	0.981***	-0.010
	(179.857)	*(-1.267)*
Greece-Portugal	0.984***	0.010**
	(207.688)	*(2.416)*
Greece-Spain	0.963***	0.012***
	(73.979)	*(3.213)*
Greece-Germany	0.968***	-0.019***
	(36.809)	*(-5.610)*
Greece-Netherlands	0.963***	-0.020***
	(87.594)	*(3.353)*

AR(1) and dummy parameter estimates testing contagion in May 2010 from equation (3.1) are shown for dynamic conditional correlation series of 10-year benchmark government bond yields between Greece vis-à-vis Ireland, Portugal, Italy, Spain, Germany and the Netherlands. Significantly positive dummy coefficients indicate further contagion evidence for May 2010. Upper numbers refer to the coefficient estimates. *, ** and * denote rejection of H0 (the parameter being equal to zero) and statistical significance at the 10%, 5% and 1% confidence level, Wald t-statistics are presented in parentheses.**

A drawback of the statistical analysis is the adequate timing of the dummy variable. The decision for a dummy exactly representing May 2010 is somewhat random. Especially in the Italian case, in which no significant dummy parameter is found, different timing of the dummy can be argued. According to Figure 3.4, correlations between Greek and Italian yields tend to increase earlier, thus providing an explanation for the insignificant May 2010-dummy.

In combination with the DCC results of Subsection 3.5.1, however, the test procedure provides nevertheless further evidence for contagion. Even though, a perfectly suitable timing of the dummy variable is not possible, a significant increase in correlations for three of four periphery countries and a significant decrease for the two core countries is affirmed. There seem to be empirical signs, that the Greek financial situation affected other countries. There are explanations for both the timing of the occurrence of contagious effects and the set of countries being hit.

3.6 Effects of Greek rating downgrades on correlations: Is there a role for non-fundamentally driven contagion?

So far, we have shown that there seem to be contagious effects at work during the European debt crisis in general. We now study if single rating agency downgrades can by themselves trigger contagious effects. If a negative rating announcement in one country significantly influences cross-country correlations, then this rating cut also influences the investors' sentiment about other countries, in which the fundamental data has remained unchanged. We would interpret this finding as evidence in favor of non-fundamentally driven contagion.

In the following, we investigate, if negative rating announcements for Greece - which we consider as independent from other European countries' fundamentals - significantly change the correlation dynamics and consequently alter the financial situation of the other periphery countries in our analysis. Evaluating announcement effects on bond co-movements is common to the literature, as exemplarily in Christiansen (2000).

3.6.1 Rating regression setup

In order to analyze the contagion effects of rating downgrades, the estimated dynamic conditional correlations from Subsection 3.5.1 are again implemented into AR(1) models. This time, the AR(1) models are extended by rating announcement dummies. Taking again Greece as the origin of the crisis, the correlations between Greece on the one side and the periphery countries Ireland, Italy, Portugal and Spain on the other side are implemented in this simple regression framework.

Greek rating announcements are assumed to be independent from the financial situation of the remaining European periphery. Our dummy variables are lagged and leaded versions of the simple dummy variable that takes on the value one on days at which Greek government debt is downgraded by one of the three leading rating agencies, and zero otherwise. The regression equation is provided in equation (3.2).

$$\rho_t = \varsigma + \lambda\rho_{t-1} + \sum_{q=-3}^{3} \theta_q D_{t+q} + u_t \tag{3.2}$$

In equation (3.2), ρ_t represents the dynamic correlations estimated in the DCC model, u_t the error term and D_t the rating announcement dummy for Greece. Because of potential information leakage from rating agencies to financial markets and because of potentially lagged information processing, the rating dummy captures leads and lags of up to three days for the rating announcement. ς, λ and θ_q are the parameters to be estimated.

3.6.2 Rating data

A dummy variable constructed with rating announcements for Greek sovereign debt between 01.01.2009 and 15.12.2011 is used in order to test the impact of rating downgrades on correlations. During that time period only negative rating cuts are published for Greece. The dummy variable takes a value of one on each day on which Fitch, Moody's or Standard and Poor's announced a downgrade and a value of zero otherwise.

For the whole sample there are 18 negative rating announcements. To get a feeling for the timings and frequencies of Greek rating downgrades, Figure 3.5 shows the development of Greek government debt ratings from the three leading rating agencies on a comparable scale.[16]

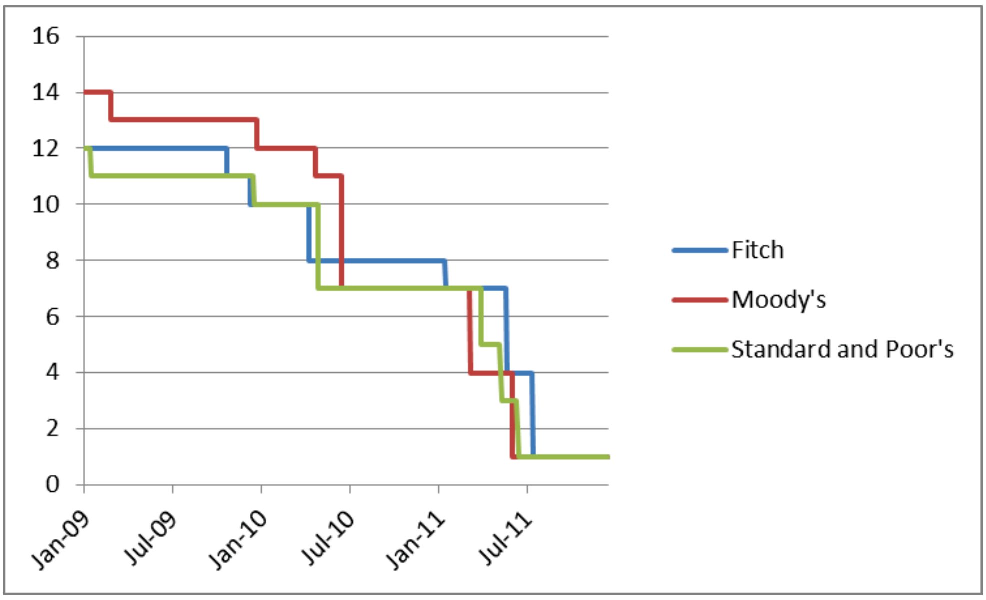
3.6.3 Results

As argued in the introduction, we define contagion in the second part of the analysis as the fast and furious reaction of government bond yields of countries other than Greece to events only related to the Greek economy. With the DCC analysis, we are able to detect that there is

[16] All rating announcement dates are directly obtained from the rating agencies' web sites. For the scaling applied to the rating development refer Table B.3.1 of Appendix B in Subsection 3.8.2.

contagion in general. A sudden increase in correlations provides evidence for contagion, yet nothing can be said about the reason for it.

Figure 3.5: Greek rating development



Greek government debt ratings by the three leading rating agencies, Fitch, Moody's and Standard and Poor's.

Things change, if there is increasing correlation immediately following a Greek announcement event. As the Greek rating announcement is independent from other countries' fundamentals, increased correlations around rating days are a sign for non-fundamentally driven contagion. The bad news on Greece is extrapolated to other economies. If Greek rating downgrades trigger correlation increases, the dummy parameter coefficient in equation (3.2) should be tested significantly positive.

If the DCC rating regression results indicate that contagious effects between Greece and other countries are present, then financial market participants – at least to some degree – transfer the financial problems of Greece to other countries in the euro area, irrespective of their underlying fundamentals. Potentially existing fundamental problems are aggravated by a rating cut of another country, in that Greece. Instead, if no contagious effects are found, then the Greek rating downgrade is seen as causing no contagion in itself to other countries' financial development.

Table 3.7 shows the results of our rating downgrade regression. Equation (3.2) is calculated for the correlations of Greece with Ireland, Italy, Portugal and Spain. We include up to three leads and lags of the dummy variable and do find some significant effects of downgrades on correlations.

Table 3.7: Rating dummy regression estimates

	Greece-Ireland	Greece-Italy	Greece-Portugal	Greece-Spain
AR(1)	**0.975*** **	**0.980*** **	**0.989*** **	**0.967*** **
	(126.884)	*(143.141)*	*(174.549)*	*(102.830)*
Rating (-3)	0.008	0.001	0.001	**0.015** **
	(1.331)	*(0.112)*	*(0.198)*	*(2.442)*
Rating (-2)	**0.020*** **	-0.008	-0.002	0.006
	(3.593)	*(-1.160)*	*(-0.435)*	*(0.959)*
Rating (-1)	0.004	**-0.014** **	**0.011* **	-0.004
	(0.646)	*(-2.051)*	*(1.955)*	*(-0.581)*
Rating (0)	0.004	-0.008	0.005	-0.001
	(0.748)	*(-1.156)*	*(0.916)*	*(-0.086)*
Rating (+1)	0.003	0.002	0.004	0.002
	(0.558)	*(0.304)*	*(0.737)*	*(0.356)*
Rating (+2)	-0.002	-0.002	**0.010* **	0.006
	(-0.344)	*(-0.288)*	*(1.845)*	*(1.022)*
Rating (+3)	0.009	-0.008	0.004	-0.008
	(1.545)	*(-1.174)*	*(0.772)*	*(-1.277)*

AR(1) and dummy parameter estimates testing for non-fundamentally driven contagion from equation (3.2) are shown for dynamic conditional correlation series of 10-year benchmark government bond yields between Greece vis-à-vis Ireland, Italy, Portugal and Spain. Rating dummy parameter estimates are calculated for the contemporaneous dummy as well as three leads and three lags of it. Significantly positive dummy coefficients indicate evidence for non-fundamentally driven contagion. Upper numbers refer to the coefficient estimates. *, ** and * denote rejection of H0 (the parameter being equal to zero) and statistical significance at the 10%, 5% and 1% confidence level, Wald t-statistics are presented in parentheses.**

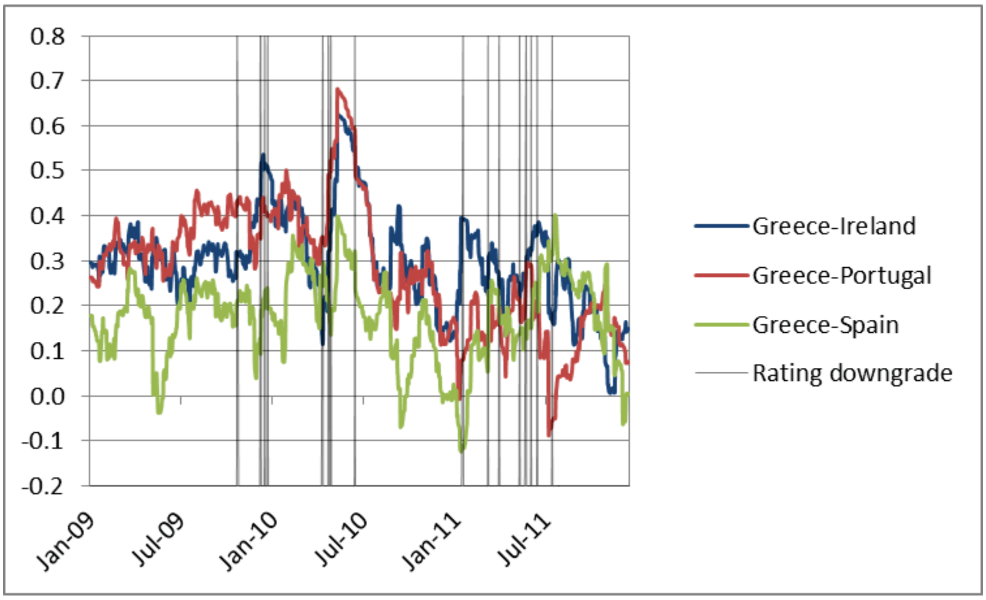
Our findings show that leads and lags of the downgrade dummy enter significantly in our regressions for the dynamic correlation coefficients for government bond yields. The level of significance varies from 1% to 10%. In the cases of Ireland, Portugal and Spain we find that in the days close to a Greek rating downgrade, the correlation with Greek government bond yields does in fact rise significantly, if only to a small extent (usually in the order of 0.01 to 0.02).

We consider these results – under the assumption that the Greek rating downgrade is exogenous to these other countries' fundamentals – as indication for a role of non-fundamentally driven contagion during the European debt crisis. Contagion is triggered by the extrapolation of Greek rating announcements.

We do not find evidence for non-fundamentally driven contagion from Greek rating downgrades to Italian bond yields. Instead, the estimated impact on the correlation is negative. Italy seems to have coped reasonably well. This might be because Italy is – at least during the period under study – generally believed to be too big for letting its governments default on debt. Hence, non-fundamental contagion from Greece to Ireland, Portugal and Spain seems to have played a bigger role than to Italy.

Summarizing, we consider these results as indication that contagion triggered by rating announcements does indeed seem to be at work for some countries within the euro area. Figure 3.6 graphically demonstrates the tendency for correlation increases on days of Greek rating downgrades.

Figure 3.6: Announcement effect of Greek ratings



Dynamic conditional correlation series of 10-year benchmark government bond yields between Greece vis-à-vis Ireland, Portugal and Spain. Vertical lines indicate days of Greek rating downgrades.

The graphic shows the correlation dynamics of Ireland, Portugal and Spain, i.e. the countries for which significantly positive rating announcement effects are found. Vertical lines indicate days of rating downgrades of Greece. For most of the announcement days it can be seen that the correlation tends to increase on days of rating downgrades.

3.7 Conclusion

We estimated dynamic conditional correlations between Greek 10-year benchmark government bond yields vis-à-vis Irish, Italian, Portuguese, Spanish, German and Dutch government bond yields according to the DCC methodology of Engle (2002) and Engle and Sheppard (2001). Based on the estimation results, we find evidence that during the European debt crisis contagion originating in Greece swept over to the European periphery. The identification of contagion is important, as knowing the causes of the European debt crisis is considered crucial in order to find the right measures to address the problems.

Based on the DCC results, we are only able to confirm the existence of contagion, yet there is nothing to be said about the reason for it. Therefore we additionally carried out an analysis relying on sovereign debt ratings in order to evaluate, if there is a role for non-fundamentally driven contagion during the European debt crisis. Bad information on Greece is extrapolated to other economies. As Greek rating cuts do have an effect on estimated bond yield correlations, our rating analysis shows that non-fundamental factors are indeed a reason for contagious pressure.

3.8 Appendix

3.8.1 Appendix A: DCC model specification

In order to estimate correlation dynamics, the principal component adjusted yields presented in Figure 3.3 are applied in a DCC model. All data is filtered for unit roots by differencing and the stationary variables are demeaned. Conditional volatilities and conditional co-movements are assumed to follow a GARCH(1,1) process. The appropriateness of this specification is tested according to Appendix B in Subsection 2.8.2.

Table A.3.1: DCC specification and diagnostic test results for the contagion analysis

	ARCH 1	GARCH 1
Greece	0.383***	0.617***
(0.457)	*(7.707)*	*(10.165)*
Ireland	0.152***	0.848***
(0.640)	*(3.499)*	*(23.407)*
Italy	0.132***	0.868***
(0.523)	*(3.005)*	*(17.615)*
Portugal	0.104**	0.896***
(0.283)	*(2.248)*	*(13.957)*
Spain	0.114***	0.886***
(0.256)	*(5.729)*	*(26.614)*
Germany	0.128***	0.872***
(0.664)	*(3.178)*	*(24.576)*
Netherlands	0.102**	0.892***
(0.839)	*(2.318)*	*(20.089)*
DCC	0.028***	0.964***
*(143.407)****	*(4.859)*	*(119.661)*

Rows 1-7 display ARCH and GARCH coefficients for the univariate conditional volatility equation (A.2.3) for Greece, Ireland, Italy, Portugal, Spain, Germany and the Netherlands. Upper numbers refer to coefficient estimates, Wald t-statistics derived from heteroskedasticity-robust standard errors are presented in parentheses. Lower numbers in parentheses below the country name refer to F-statistics derived from the ARCH-LM test. A sufficiently high F-statistic leads to rejection of the H0 of no remaining ARCH.

Row 8 displays ARCH and GARCH coefficients for the multivariate conditional covariance equation (A.2.5). Upper numbers refer to coefficient estimates, Wald t-statistics derived from modified standard errors are presented in parentheses. The lower number in parentheses below “DCC” refers to the F-statistic derived from the OLS-tests for constant conditional correlation. A sufficiently high F-statistic leads to rejection of the H0 of constant conditional correlation.

***, ** and *** denote rejection of H0 and statistical significance at the 10%, 5% and 1% confidence level.**

Table A.3.1 provides the estimation results of the DCC model proposed by Engle (2002) and Engle and Sheppard (2001) and diagnostic test results for the appropriateness of the specification. The table can be read like the tables in Appendix B of Subsection 2.8.2. All parameter estimates are significant. There are no signs for an inadequate specification of the DCC model.

3.8.2 Appendix B: Rating scale

Figure 3.5 relies on a scaling of the sovereign debt ratings of the three leading rating agencies. Table B.3.1 provides the applied rating scale.

Table B.3.1: Rating scale

	Fitch	Moody's	Standard and Poor's	Description
17	AAA	Aaa	AAA	Prime
16	AA+	Aa1	AA+	High grade
15	AA	Aa2	AA	
14	AA-	Aa3	AA-	
13	A+	A1	A+	Upper medium grade
12	A	A2	A	
11	A-	A3	A-	
10	BBB+	Baa1	BBB+	Lower medium grade
9	BBB	Baa2	BBB	
8	BBB-	Baa3	BBB-	
7	BB+	Ba1	BB+	Non-investment / speculative grade
6	BB	Ba2	BB	
5	BB-	Ba3	BB-	
4	B+	B1	B+	Highly speculative grade
3	B	B2	B	
2	B-	B3	B-	
1	CCC or worse	Caa1 or worse	CCC+ or worse	Substantial risk or worse

Scaling applied to the rating development provided in Figure 3.5.

Chapter 4

Contagion in the market of financial service providers: Interdependence of problems in the financial system

4.1 Preface: From country level to company level

The concept of contagion, which is already defined in the Preface of Chapter 3 in Subsection 3.1, is not limited to the country level analysis. Also on the company level, particularly in the financial sector, various kinds of problems can spread from its origin to a larger system.

The threat emanating from contagion in the financial sector is a significant research topic. If there ever was any doubt about its importance, the financial crisis starting in 2007 and its aftermath dispelled it. Analyzing interdependences within the financial service providers and the proper regulation of all relevant market participants remains a crucial task. Paul Krugman vividly describes the problems arising from interdependencies of various actors in the financial system:

"When Bear Stearns, another of the original five major investment banks, got in trouble in March 2008, the Fed and the Treasury moved in - not to rescue the firm, which disappeared, but to protect the firm's "counterparties," those to whom it owed money or with whom it had made financial deals. There was a widespread expectation that Lehman would receive the same treatment. But the Treasury Department decided that the consequences of a Lehman failure would not be too severe, and allowed the firm to go under without any protection for its counterparties. Within days it was clear that this had been a disastrous move: confidence plunged further, asset prices fell off another cliff, and the few remaining working channels of credit dried up." (Krugman, 2008, p. 178)

Chapter 4 theoretically addresses these problems arising from the interdependences in the financial system. Findings document, that insolvency or liquidity shortage of one financial service provider can quickly translate into severe problems for other financial service providers. Due to such contagious effects between financial institutions, the proper functioning of financial markets can be put on the line.

Distress of single companies can infect the financial system as a whole. While under certain conditions market participants are unable to solve this problem with contractual mechanisms on their own, prudent regulation and governmental provision of external liquidity is asked for in order to safeguard against this threat.

4.2 Introduction

For a variety of different reasons, financial service providers can be exposed to severe refinancing problems. Due to the high degree of interrelations in today's financial system, insolvency or liquidity shortage of one market participant can infect other, seemingly financially sound companies.

If an idiosyncratic liquidity shock hits a small number of market participants, refinancing problems can quickly translate to several others. With an aggregate shock hitting several market participants, problems are even worse. With a huge amount of financial service providers either failing or being close to failing at the same time, the financial crisis beginning in 2007 represents a prominent example of contagious effects resulting from heavy interdependences in the financial sector. This chapter provides a theoretic model which describes the threats emanating from a highly interrelated financial system.

Chapter 4 is structured as follows: Subsection 4.3 reviews the literature on this topic. In Subsection 4.4, the basic setup of the model is explained. In this setup, there are financial market interdependences, due to which insolvency or illiquidity problems can spread from one company to another. It is shown, that even if the friction of limited pledgeability restrains the market mechanisms, there are nevertheless risk insuring state contingent contracts which can provide complete insurance and thus avert perturbations caused by interdependences.

The implementation of a further friction in form of missing management incentives renders the state contingent contracts inefficient and reveals the incentive of rational market participants to deviate to other forms of contractual agreements under certain conditions. In Subsection 4.5 the dominance of debt contracts in such circumstances is derived. Debt contracts are designed in a way that they are the reasonable option for financial service providers. The participation constraints of each contractual partner are fulfilled. Capital providers are perfectly insured in normal times and contagious effects stemming from the counterparty's financial problems only occur in very rare cases. In the incidence of such a worst case scenario, however, debt contracts lead to severe financial disturbances.

The history of financial crises proves that financial institutions are likely to enter into arrangements which work smoothly in normal times but which cannot be handled in highly unlikely, but highly critical situations. Subsection 4.6 derives the low likelihood of a contagious crisis and demonstrates that the proper functioning of the financial system can be drastically disturbed if a severe enough shock arises. Subsection 4.7 outlines the results if idiosyncratic shocks are replaced by aggregate ones. All issues discussed without aggregate shocks can easily be shown to worsen dramatically.

The inability of private market participants to prevent great damages resulting from contagion calls for governmental intervention mechanisms to deal with that problem. In Subsection 4.8, policy recommendations are provided to avert the threats inherent in the interconnected financial system. It is demonstrated that prudent regulatory action can allow for more unobstructed functioning of the financial markets. Specifically, higher equity capital requirements for financial service providers and governmental provision of liquidity in shock situations can break up the contagious connection between different financial service providers. Section 4.9 concludes.

4.3 Literature

There is extensive literature on reasons for contagion in the financial system and on contracts fighting this problem. The overview of related literature presented here serves the purpose of identifying important contributions to this field, which influenced the direction and progress of this work.

Insolvency or illiquidity do not only affect the directly hit company, but can also negatively affect contractually related enterprises. This model analyzes the reasons, why market participants are unable to protect the own financial situation against this threat of contagion. While contractual agreements can prevent these problems to spread to the overall financial system in frictionless markets, they do not work if market mechanisms are disturbed. Risk insuring state contingent contracts provide insurance in complete markets, but are rendered infeasible by frictions under certain conditions. Instead, debt contracts are shown to dominate in such a market place. While providing complete insurance in normal times, such debt contracts can lead to systemic contagion in the wake of severe shocks. Comparably, Dang et al. (2012) identify debt as welfare maximizing contract. The authors show that debt minimizes asymmetric information problems. However, they also demonstrate that debt contracts can cause a systemic risk to the economy's liquidity provision if an aggregate shock occurs.

Throughout Chapter 4, insolvency and liquidity shortages are derived as a result of a combination of market frictions and unlucky investment behavior. The total of generated investment values turns out to be insufficient to meet all payment requirements when they are due. Thereby, certain market participants can become liquidity constrained. The problem of insufficient investment value is frequently discussed in the literature. Holmström and Tirole (2011) define this scenario of insufficient investment value as a shortage of inside liquidity. They argue that too low inside liquidity can be mitigated by the supply of outside liquidity. Outside liquidity refers to liquidity provided by international markets or the government. A policy measure in which the government uses its taxation power to redistribute liquidity from consumers to the financial system in crisis times is also discussed as a potentially reasonable intervention in this model setup.

For collateralized borrowing, the investment value has a crucial impact on the refinancing ability of market participants. Once a negative shock devalues the investment, funding dries out and the remaining source of liquidity is proceeds from the sale of assets. The asset sale, however, further debases the investment value thereby rendering debt capital financing even more difficult. Brunnermeier and Pedersen (2009) show this link between the ease with which assets can be traded and the ease with which external funding can be obtained. The authors demonstrate that this interaction of the so-called market and funding liquidity can lead to severe refinancing problems. A similar reinforcing spiral between devalued investment and subsequently forced asset sales serves as the main mechanism in the development of contagion problems in this model of Chapter 4.

Kiyotaki and Moore (1997) construct a model which shows persistent fluctuations in output and asset prices as a result of temporary shocks. Due to collateralized borrowing, the value of invested assets represents the credit constraints of the borrowers. In the dynamic setting, these constraints and the asset prices influence themselves vice versa. The implications of such a connection between constraints and assets also help to explain the threat of insolvency and illiquidity of the interconnected market participants in this model.

Benmelech and Bergman (2010) assume that lenders which are insured by collateralized borrowing agreements are not able to operate the received collateral due to its limited pledgeability.[17] So-called credit traps, situations in which liquidity is hoarded by intermediaries instead of lent out, are described as a result of the subsequently endogenized liquidation values of collateral. The friction of limited pledgeability is also crucial for the contagion scenario derived in here, as it renders it impossible that the insured lender averts the spreading of financial problems.

Before the contagion mechanism is set in motion, an initial shock sparks tightened borrowing conditions. Diamond and Rajan (2011) exemplarily discuss illiquidity of assets as a potential reason for depressed lending. In comparison to that, the remainder of Chapter 4 describes borrowing constraints as a result of pure chance. Once the economic situation allows for an unlucky combination of investment projects, bad luck decides about winners and losers and about the likelihood of contagious pressure. In accordance with the notion of suchlike defined shocks, Ivashina and Scharfstein (2010) show that during the financial crisis, specifically in the last quarter of 2008, loan provision to below investment grade borrowers decreased equally strongly as loans to investment grade borrowers. Consequently, different credit quality does not necessarily play the crucial role in the decision for debt provision. Good and bad luck is also important even for investment grade borrowers.

Allen and Gale (2005) show the occurrence of price volatility and financial crises caused by defaulted debt repayments in the wake of small liquidity shocks. While in complete markets with contingent contracts no asset sale in order to meet liquidity requirements is necessary, tapping the market liquidity of assets is indispensable in incomplete markets. In order to cover the opportunity costs of holding liquidity, the liquidity suppliers charge a premium in the form of low asset prices from the liquidity demander. Higher liquidity needs lead to lower asset prices and the subsequent requirement of more asset sales. Based on that mechanism, the authors derive a backward bending supply curve of assets. This unusual supply structure is

[17] Holmström and Tirole (2011) provide a variety of reasons defending the assumption of limited pledgeability.

also implemented into this model. With the help of this feature, it is demonstrated that charging a liquidity premium is not even necessary to trigger a crisis.

4.4 Basic setup

All market participants operate in the financial system. There are two distinct types of financial institutions. The first group consists of risk neutral providers of debt capital. Their business background allows them to hand out loans to the economy. One can think of commercial banks, credit unions, depository banks or other providers of credit. Among the customers demanding credit is the second type of financial institutions.

The second group consists of risk neutral consumers of debt capital. Within this group, there is any kind of broker and dealer whose business is crucially dependent on the access to external debt capital. Among others, these can be hedge funds, private equity companies, investment vehicles or banks with no or not noteworthy deposit business. This second type of financial service provider operates in particular specialized fields. Within their particular fields, they have superior knowledge and experience as compared to any other company not operating in this specialized area. In order to make investments in projects representing their particular specialized field, the service providers use equity capital but additionally require external debt capital.

The service providers of the second group can buy and sell the assets underlying their investment projects. A priori, except for the own specialization, all members of this second group of market participants are equal. There are no differences when it comes to experience, ability or efficiency. Some shock, however, can differentiate those financial service providers into subgroups with lucky or unlucky investment behavior.

> The setup can best be explained with a constructed example. One can think of the second type of financial service providers as being two private equity companies. Those two companies are located in countries B and C. Each company is specialized in investments concerning its own country and both are specialized in investments in the field of natural resources. Besides the unique experience in home country investments both companies are identical. The investment strategy

of the private equity companies consists of buying companies, collecting returns from these investments and selling them afterwards. In order to realize the investments, the private equity companies rely on leverage. The provider of the required debt capital can be thought of as a commercial bank from the first type of financial institutions, denoted as bank A.[18]

Within the economy, there is a finite but large number N_0 of investment opportunities, which B and C finance in equal parts (both B and C finance $0.5 * N_0 = N_1$). After investing, each project is represented by an asset, so the terms project and asset are interchangeable. The projects have to be financed in t=0 and realize their inherent value in t=2. Besides that payoff, each project generates a return of Ω per period.

The aggregated inherent value of the entire N_0 projects within the portfolio is known in t=0. In detail, there are two different types of projects in the portfolio, some known fraction η of the projects has a value of Z and the remaining fraction $(1-\eta)$ has a value of $V < Z$.[19] In total, this yields an aggregate value of the entire portfolio provided in (4.1).

$$\eta N_0 Z + (1-\eta) N_0 V \tag{4.1}$$

In t=0, nobody knows which specific project will have a high value and which one will have a low value, consequently the two different types of projects are not distinguishable yet.

In t=1, the progress of the different projects can be observed. From that point on, the type of asset can be recognized by every market participant in the economy. Still, a fraction η of all N_0 projects has a value of Z and a fraction $(1-\eta)$ a value of V, leading to the identical portfolio value as in t=0, but now the two types of assets can be distinguished. Additionally,

[18] The results of the model can best be derived for an example with one financial service provider of the first type, denoted as A and two financial service providers of the second type, denoted as B and C. However, generalizations are possible. For an informal discussion refer to Appendix G in Subsection 4.10.7.
[19] The investment value is assumed to be ex ante determined. Even in the absence of volatility in the investment value, all further results hold.

the good development of the high value projects allows them to be tradable in t=1. For the low value projects it is assumed, that they are non-tradable.[20]

> Continuing the example, one can think of countries B and C sharing the same border. In t=0, both private equity companies B and C purchase an equal amount of land units on its respective side of the border. There are N_0 units of land in total, half of it in country B, the other half in country C. Initially it is known that the land might have exploitable natural resources. In detail it is known from earlier geological research, that a fraction η of the N_0 units has resources with a net worth of Z. The other fraction $(1-\eta)$ lacks resources and can only be used for construction. Therefore those units only have a smaller net value of V. The different types of units cannot be distinguished before the land development has started.
>
> Between periods t=0 and t=1 the land is developed and consequently the type of land unit becomes common knowledge. While working on both types of land, some side product can be realized on either kind of land, therefore each unit of land, independently of the type, additionally generates per period return of Ω.
>
> From t=1 on, only the assets underlying the units with natural resources can be traded. Both private equity companies B and C are specialized in the field of natural resources, consequently they can trade that international assets in between themselves. The assets underlying the construction units cannot be traded. Each company is only specialized in its own home country and the construction sites are immobile and country specific. As a consequence, these national assets are non-tradable.

Realizing some fraction of the N_0 projects in t=0 costs exactly that fraction of the value of the entire project portfolio. The price of one single of the N_0 projects is $\eta Z + (1-\eta)V$. B and C split the whole amount of projects equally in between themselves and require debt capital in order to finance those investments, so they need to borrow from A. In order to safeguard

[20] Following Caballero and Krishnamurthy (2001), one can also think of tradable goods as being internationally demanded and of non-tradable goods as being domestically demanded.

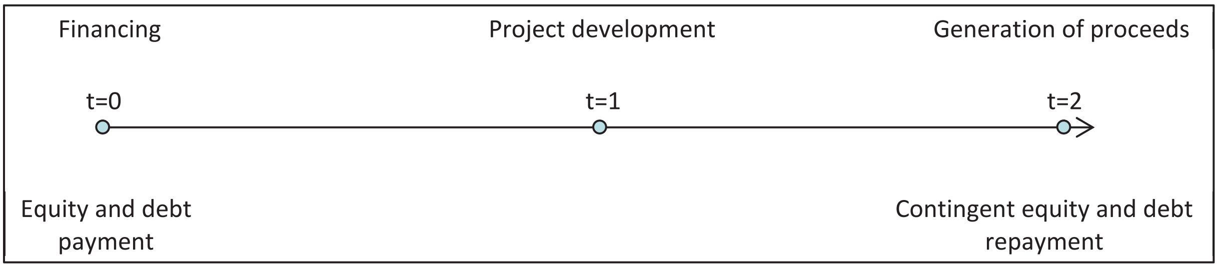
against default, A strives to implement some mechanism which guarantees full repayment of the funds provided to B and C.

4.4.1 State contingent contract

In this basic setup it is possible for A to offer a fully insuring state contingent contract to B and C. This contractual agreement provides a secured guarantee that in t=2, A will receive full repayment of all the funds provided in t=0.

The contract works as follows: In t=0, A provides long-term financing (i.e. financing from t=0 until t=2) for B and C. As B and C are a priori equal, both receive an identical fraction $\rho < 1$ of their investment capital as credit. A contractually obliges them to repay the received funds in t=2 conditionally on the state of the world. The timing of the state contingent contract is provided in Figure 4.1. Above the timeline, the development of the projects is explained, below the timeline, the actions and capital flows of A, B and C are described.

Figure 4.1: Timing in a state contingent contract



The whole investment volume of B and C serves as collateral for A. As soon as either B or C defaults, A gains access to the respective investments. In t=0, A does only provide a fraction $\rho < 1$ and not the whole investment volume for B and C because of limited pledgeability. The investments of B and C are worth less for A, because A is not specialized in their particular fields of investment. Once A receives the investments as collateral, A is not able to operate those adequately and can only liquidate them with a payoff discounted by the factor ρ. Also, A is not able to generate the return of Ω for the assets. By only providing a fraction of ρ as financing capital, A can still get fully reimbursed from the proceeds of the collateral, if B or C were willing to default right from the beginning.

In t=2, B and C have to repay the same fraction ρ of their proceeds. The contract is state contingent, as the repayment is higher in a good state of the world with high proceeds and lower in a bad state of the world with low proceeds. Using this kind of contract, A can completely safeguard its own interests, as full repayment of all funds is guaranteed. This is proven in the following.

In t=0, both B and C buy N_1 assets, and each market participant (A, B and C) expects for both B and C, that a fraction η of their investment is of high value Z and a fraction $(1-\eta)$ is of low value V. Consequently, the two portfolios of B and C combined have exactly the known aggregated value of the N_0 projects in the economy's investment portfolio given in (4.1). The N_1 assets of each B and C cost (4.2).

$$\frac{\eta N_0 Z + (1-\eta) N_0 V}{2} = \eta N_1 Z + (1-\eta) N_1 V \tag{4.2}$$

For both B and C, A provides a fraction ρ of the investment capital in form of debt capital and the fraction $(1-\rho)$ needs to be equity financed. The credit pay-out of A to both B and C is identical and in aggregate amounts to (4.3).

$$-2[\eta N_1 Z + (1-\eta) N_1 V]\rho = -[\eta N_0 Z + (1-\eta) N_0 V]\rho \tag{4.3}$$

In t=1, the type of the assets can be recognized after the development of the projects. It turns out that one service provider (without loss of generality assumed to be B in the following) invested without knowledge and based on pure chance in a lower than average fraction $\varepsilon < \eta$ of the high value asset and consequently in a higher than average fraction $(1-\varepsilon) > (1-\eta)$ of the low value asset.

Contrary to that, C invested also without knowledge in a higher than average fraction $\gamma > \eta$ of the high value asset and a lower than average fraction $(1-\gamma) < (1-\eta)$ of the low value asset.[21] Therefore in t=1, the value of B's portfolio is lower (4.4) and the value of C's portfolio is higher (4.5) than it was expected in t=0.

[21] The distribution of the random variables ε and γ is discussed in Subsection 4.6.

$$\varepsilon N_1 Z + (1-\varepsilon)N_1 V < \eta N_1 Z + (1-\eta)N_1 V \tag{4.4}$$

$$\gamma N_1 Z + (1-\gamma)N_1 V > \eta N_1 Z + (1-\eta)N_1 V \tag{4.5}$$

For rational expectations, the in t=0 expected value of the two investment portfolios of B and C combined must be equal to the realized combined investment value in t=1. Therefore the amount of high value assets and the amount of low value assets must be equal in t=0 and t=1. This is assured by (4.6).

$$[\eta N_1 Z + (1-\eta)N_1 V] + [\eta N_1 Z + (1-\eta)N_1 V]$$
$$= [\varepsilon N_1 Z + (1-\varepsilon)N_1 V] + [\gamma N_1 Z + (1-\gamma)N_1 V]$$

$$\Rightarrow \varepsilon N_1 + \gamma N_1 = \eta(N_1 + N_1)$$

$$\Rightarrow \varepsilon = 2\eta - \gamma \tag{4.6}$$

However, even though the value of the investments changed for B and C in t=1, the credit conditions are not renegotiated, as A provided long-term financing, which lasts until t=2. In t=2, the investments yield a payoff worth exactly the assets' value in t=1 and a return of Ω per asset per period. As the repayment in t=2 is state contingent and amounts to the factor ρ of all realized proceeds, B might have to repay less than it received in t=0 due to its lower than expected realized investment value. C has to repay more than it received in t=0, as the investment value turned out to be higher than expected. Specifically, the repayment of B and C for A amounts to (4.7) and (4.8):

$$[\varepsilon N_1 Z + (1-\varepsilon)N_1 V]\rho + 2N_1\Omega\rho \tag{4.7}$$

$$[\gamma N_1 Z + (1-\gamma)N_1 V]\rho + 2N_1\Omega\rho \tag{4.8}$$

This kind of payment schedule allows for a secured repayment of all funds for A, as the total of the repayments in t=2 (4.7+4.8) is higher than the pay-out in t=0 (4.3) under rational expectations (4.6). In total, A additionally receives interest amounting to $4\Omega N_1\rho$.

4.4.2 Participation constraints

For A, it is rational to sign the state contingent contract. For B and C, the contract works as insurance. As both a priori do not know which one of them will make the unlucky investment, they can sign such a contract in order to insure against a loss situation. They will, however, only sign the contract if their expected investment return is larger than zero.

The payments of the unlucky service provider are summarized in (4.9). The first term represents the equity pay-out in t=0, the second and third term the payment to equity in t=2. Accordingly, the payments of the lucky service provider are summarized in (4.10). The lucky service provider gains from the situation, but it has to spend some of its profits for buying an insurance, which is then not used by itself, but by the unlucky one.

$$\begin{aligned} &-[\eta N_1 Z + (1-\eta)N_1 V](1-\rho) + [\varepsilon N_1 Z + (1-\varepsilon)N_1 V](1-\rho) + 2N_1\Omega(1-\rho) \\ &\qquad = -(Z-V)(\eta-\varepsilon)N_1(1-\rho) + 2N_1\Omega(1-\rho) \end{aligned} \tag{4.9}$$

$$\begin{aligned} &-[\eta N_1 Z + (1-\eta)N_1 V](1-\rho) + [\gamma N_1 Z + (1-\gamma)N_1 V](1-\rho) + 2N_1\Omega(1-\rho) \\ &\qquad = (Z-V)(\gamma-\eta)N_1(1-\rho) + 2N_1\Omega(1-\rho) \end{aligned} \tag{4.10}$$

The risk neutral service providers B and C will make that kind of deal, as for B and C there are positive expected profits in the state contingent contract, as will be shown in the following.

As all other parameters $(N_1, Z, V, \rho, \eta, \Omega)$ are exogenously ex ante given, the expected value of the profit depends on the realizations of ε and γ. Within some boundaries there are several potential $\varepsilon - \gamma -$combinations.[22] Examining one arbitrary combination, $\varepsilon_1 - \gamma_1$, it is straightforward that independently of the distribution of ε and γ, the probability for B to draw ε_1 is equal to the probability of C to draw γ_1. As $\varepsilon_1 = 2\eta - \gamma_1$ by rational expectations (4.6), C must draw γ_1 if B draws ε_1. Reason to the same argument, the probability for B to draw γ_1 is equal to the probability for C to draw ε_1. C must draw ε_1 if B draws γ_1.

[22] The boundaries are derived in Appendix A in Subsection 4.10.1.

A priori, both B and C can be either lucky or unlucky. Recognizing that B and C are exactly identical when drawing the projects in t=0, it is clear that the probability for B to draw $\varepsilon_1 < \eta$ is equal to the probability for C to draw $\varepsilon_1 < \eta$. This yields in total that B and C have an equal chance of drawing ε_1 and that probability is also equal for drawing γ_1. The same is true for each other possible $\varepsilon_i - \gamma_i$ −combination (4.11).

$$\mathrm{Prob}(\mathrm{B} = \varepsilon_i) = \mathrm{Prob}(\mathrm{C} = \gamma_i) = \mathrm{Prob}(\mathrm{C} = \varepsilon_i) = \mathrm{Prob}(\mathrm{B} = \gamma_i)\ \forall i$$

$$\sum_{i=1}^{\infty} \mathrm{Prob}(\mathrm{B} = \varepsilon_i) = \sum_{i=1}^{\infty} \mathrm{Prob}(\mathrm{B} = \gamma_i) = \sum_{i=1}^{\infty} \mathrm{Prob}(\mathrm{C} = \varepsilon_i) = \sum_{i=1}^{\infty} \mathrm{Prob}(\mathrm{C} = \gamma_i) \quad (4.11)$$

Using the fact that B and C have equal probabilities deciding about their investment status (4.11), rational expectations (4.6) and the pay-out structures of the unlucky (4.9) and the lucky service provider (4.10), equation (4.12) shows exemplarily for B that in t=0 the service providers have a positive expected investment value of $2N_1\Omega(1-\rho)$.

$$E_0(\mathrm{B}) = \{\sum_{i=1}^{\infty} \mathrm{Prob}(\mathrm{B} = \varepsilon_i)[-(Z-V)(\eta - \varepsilon_i)\, N_1(1-\rho)]$$

$$+ \sum_{i=1}^{\infty} \mathrm{Prob}(\mathrm{B} = \gamma_i)[(Z-V)(\gamma_i - \eta) N_1(1-\rho)]\} + 2N_1\Omega(1-\rho)$$

$$= 2N_1\Omega(1-\rho) \quad (4.12)$$

Concluding, in the basic setup, A can offer a state contingent contract which guarantees full repayment of all funds and interest. In addition, B and C are willing to sign the contract, as there are positive expected profits. The state contingent contract is feasible. However, things change after small deviations from the basic setup.

4.5 Results in a market with missing management incentives

The results of Subsection 4.4 do not hold once small deviations from the basic setup are implemented into the model. Allowing for the possibility of bad management efforts as additional friction, it will be shown that a state contingent contract is not a reasonable option for A anymore. The debt contract, which is implemented instead, reveals a deceptive security.

Bad management disturbs the proper functioning of the markets as follows: Both B and C install managers responsible for the surveillance of diligent working within their companies. The salary of those managers is derived from the increase in equity capital in t=2, consequently the managers receive some form of performance payment. As long as the managers themselves work diligently, all projects develop as they should do. However, once the managers do not display the due diligence, each project sustains a fixed value reduction amounting to σ per period. Additionally, the projects then do not generate a return of Ω.

Between t=0 and t=1, the managers do not know if they work for the lucky or the unlucky service provider. As performance payment still seems possible for both, the managers work diligently during that period. In t=1 it turns out that C is the lucky and B is the unlucky service provider. From that moment on it can be recognized that B will generate a decrease and C an increase in equity capital. While for the manager of C the performance payment is still an incentive to work diligently, the manager of B has no incentive anymore and displays a lack of diligence between t=1 and t=2. Therefore, each of the N_1 projects of B sustains a value reduction of σ and does not generate a return during t=1 and t=2.

4.5.1 State contingent contract

Under a certain condition, a state contingent contract delivers guaranteed losses for A due to the missing management incentives. As the management of C works diligently all the time, the repayment of C remains identical as in (4.8). Due to its mismanagement, however, B does not generate the return of Ω in the second period and the investment value decreases by σ. The friction causes the repayment of B to decrease to (4.13).

$$\big(\varepsilon N_1(Z-\sigma)+(1-\varepsilon)N_1(V-\sigma)\big)\rho + N_1\Omega\rho \tag{4.13}$$

Using rational expectations (4.6), a new pay-out scheme for A given in (4.14) can be derived. The first term captures the debt pay-out of A in t=0, the second and third term the repayments of B and C in t=2.

$$-2(\eta N_1 Z + (1-\eta)N_1 V)\rho + \big(\varepsilon N_1(Z-\sigma) + (1-\varepsilon)N_1(V-\sigma)\big)\rho$$
$$+(\gamma N_1 Z + (1-\gamma)N_1 V)\rho + 3N_1 \Omega\rho = N_1\rho(3\Omega - \sigma) \qquad (4.14)$$

This pay-out situation represents a guaranteed loss once the condition $3\Omega < \sigma$ is assumed. Then, B's bad management makes it impossible for A to offer the state contingent contract. A different kind of security mechanism must instead be installed.

4.5.2 Debt contract

A debt contract is another possibility for A to safeguard the funds provided to B and C. In such a contract, A lends a particular fraction δ of the investment value to both B and C and requires the total investments as collateral. As in the state contingent contract, B and C borrow against the expected value of their specific investment. As soon as one of them is not able to repay as the timing schedule requires, A receives the collateral and the defaulting financial service provider disappears from the marketplace.

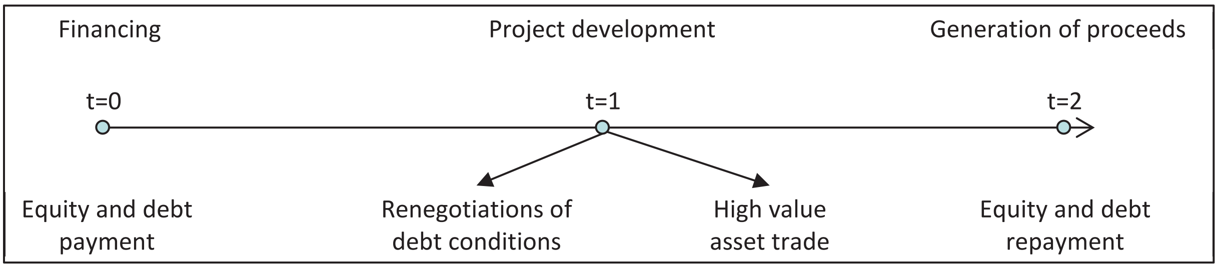
In comparison to the state contingent contract, the margin is not only due to the limited pledgeability, but also in order to diminish the default probability. As the contract is not state contingent, potential value losses of one debtor are not directly captured by the other one. The margin assures that potential value losses are initially captured by subordinated equity capital.[23] Comparing the margin in the two types of contracts, $\rho > \delta$, as the margin serves two purposes in the debt contract as compared to one in the state contingent contract and thus the debt contract requires more equity capital provision.

A charges per period interest amounting to Φ per financed asset. The interest has to be paid in t=1 and t=2. The exact value of Φ can be derived from the participation condition of A. For the subsequent results it is only important to assume that it is smaller than the exogenously given return Ω. A provides short-term financing with credit conditions being renegotiated according to the collateral value in t=1. If the collateral value of the borrower decreased, a part of the funds has to be paid back, if the collateral value increases, more funds can be obtained. High value assets can be traded in t=1. In t=2, after the projects had realized their

[23] Margin constraints in collateralized borrowing are common practice in reality. Refer to Brunnermeier and Pedersen (2009) for examples.

proceeds, the remaining debt capital has to be repaid. The timeline for the debt contract is provided in Figure 4.2.

Figure 4.2: Timing in a debt contract



The debt contract turns out to provide a negative expected value for A in the basic setup without missing management incentives. In t=0, A provides a fraction δ of B and C's investment value as debt capital. With the beginning of t=1, the realizations of ε and γ become common knowledge. As there is no potential for a bad management in the basic setup, all proceeds and returns, which both B and C will have gathered until t=2, are also common knowledge. This allows for two scenarios in the basic setup:

In the first scenario, the future funds of B are lower than the required payments and B is insolvent. The condition for this first scenario is given in (4.15). The first term of the left hand side of the equation represents the required repayments, the second term the required interest. The first term of the right hand side of the equation captures B's investment payoff in t=2, the second term the per asset return.

$$(\eta N_1 Z + (1-\eta) N_1 V)\delta + 2N_1\Phi > \varepsilon N_1 Z + (1-\varepsilon) N_1 V + 2N_1\Omega$$

$$\Rightarrow \varepsilon < \varepsilon^* = \eta\delta - \frac{V}{Z-V}(1-\delta) - \frac{2(\Omega-\Phi)}{Z-V} < \eta \qquad (4.15)$$

In the second scenario, the future funds of the unlucky service provider B are higher than the borrowed funds and the required interest and B is solvent. As there is no uncertainty about the management effort, A knows that B is solvent and future solvency is not threatened. A has no reason to renegotiate the credit conditions in t=1. B will deliver all repayments and all interest in t=2. As the lucky service provider C pays back in any case, A does not incur losses in the second scenario. In the first scenario, however, B is not able to make all payments as contractually agreed on. If ε turns out to be small enough, B defaults on the interest and additionally on the repayments. If the collateral is not enough to counterbalance the missed payments, A incurs losses.[24]

The debt contract is nevertheless a reasonable option for A, once the model allows for management errors. Still, the contract does not guarantee losses of zero, but it will provide an expected value of at least zero. The state contingent contract is dominated and the problems arising from the additional friction can be ruled out. If the basic setup is extended for missing management incentives, three scenarios are possible. In the first scenario, B is insolvent, as in the basic setup. In the other two scenarios, B is solvent, but only able to repay all funds under certain conditions. If these conditions are not met, B is solvent but illiquid.

4.5.2.1 Illiquidity

As long as (4.15) is not fulfilled, B is solvent. However, the problem of illiquidity can emerge. In t=0, A pays out debt capital amounting to (4.16) to both B and C.

$$-(\eta N_1 Z + (1-\eta) N_1 V)\delta \tag{4.16}$$

In t=1, the credit conditions are renegotiated according to the development of the collateral value which B and C can offer. With the development of the projects, the collateral value of B decreases and it becomes harder for B to roll over the loans. B has to pay back the difference between the two short-term credits granted in t=0 and in t=1 and therefore a liquidity requirement for B arises. Due to this shortage of funding liquidity, B needs to rely on the market liquidity of its assets, i.e. B needs to obtain the required liquidity by selling tradable high value assets. If the price at which B can sell is high, fewer assets need to be sold than if the price is low. The resulting asset supply function (4.17) is therefore downward sloping.[25]

[24] The particular conditions for losses will be derived in Subsection 4.5.2.2. Here, the only intention is to demonstrate that a debt contract can cause losses in the basic setup.
[25] The asset supply function (4.17) is derived in Appendix B in Subsection 4.10.2. The derivation for the asset demand function (4.18) works accordingly.

$$Q_B(P) = \frac{(Z-V)(\eta-\varepsilon)N_1\delta - N_1(\Omega-\Phi)}{P-Z\delta} \tag{4.17}$$

The collateral value of C increases with the development of the projects in t=1. C receives more debt capital from A as compared to t=0. This additional liquidity can be used to buy assets from B. As with lower prices more assets can be bought from the surplus liquidity, the asset demand function (4.18) is also downward sloping.

$$Q_C(P) = \frac{(Z-V)(\gamma-\eta)N_1\delta + N_1(\Omega-\Phi)}{P-Z\delta} \tag{4.18}$$

As B and C trade the assets in between themselves, their aggregated portfolio value remains identical in t=0 and t=1. [26] Consequently, as A provides funds against that portfolio value and the margin δ does not change, also the total funds provision remains the same as long as every market participant repays as contractually agreed on: There is only redistribution. The funds which B loses are directly readdressed to C.

The returns Ω, which B and C receive, are greater than the interest Φ, which they have to pay each period. The aggregate credit provision of A remains identical. The difference of return and interest improves the aggregate liquidity situation of B and C. The aggregate liquidity supply is therefore theoretically sufficient for both B and C. As a result thereof, the asset demand of C (4.18) at any price is higher than the asset supply of B (4.17). This can also be derived using the rational expectations condition (4.6).

In order to remain liquid, B needs to collect enough proceeds from its sale of high value assets. If the asset price falls, B must sell more assets in order to meet its financial obligations. If the asset price falls to a certain boundary value $\underline{P_B}$ (4.19), B must sell all of its high value assets. If the price falls below that value, B has no chance to remain liquid. The asset supply at the boundary price must be equal to B's full amount of high value assets in t=0.

[26] For A it is not reasonable to engage in that trade. The discount A would sustain because of the limited pledgeability is too high. Refer to Appendix C in Subsection 4.10.3 for a detailed discussion of this friction.

$$Q_B\left(\underline{P_B}\right) = \varepsilon N_1$$

$$\Rightarrow \underline{P_B} = \frac{\eta\delta(Z-V) - (\Omega - \Phi)}{\varepsilon} + V\delta \qquad (4.19)$$

C can use its additional liquidity to buy assets from B. If the asset price falls, C can buy more assets with the additional liquidity at hand. If the asset price falls to a certain boundary value $\overline{P_C}$ (4.20), C has exactly enough liquidity to buy all of B's high value assets. The asset demand at this price is equal to B's amount of high value assets in t=0.

$$Q_C\left(\overline{P_C}\right) = \varepsilon N_1$$

$$\Rightarrow \overline{P_C} = \frac{\eta\delta(Z-V) + (\Omega - \Phi)}{\varepsilon} + V\delta \qquad (4.20)$$

Recognizing that the asset demand is always higher than the asset supply leads to the conclusion that the minimum price which B needs to receive for all of its Z-assets is smaller than the maximum price which C could pay for the same amount of Z-assets. This can again be derived using the rational expectations condition (4.6). A scenario in which C uses all of its surplus liquidity to buy high value assets of B and thereby fills B's liquidity gap is consequently possible, however, not secured.

Extending the basic setup for missing management incentives, allows for three scenarios, the first of which is insolvency according to condition (4.15). In the second scenario, B is solvent and liquid. Then the boundary price which B needs to receive in order to remain liquid when selling all high value assets is smaller than the fundamental value, $\underline{P_B} < Z$. C is in a position of power, as only B is in liquidity trouble and C has surplus liquidity to provide. Consequently, C can charge a liquidity premium from B. That premium has the form of undervalued prices, at which C buys the high value assets from B. C does not pay the fair value for B's assets, but only the minimum price $\underline{P_B}$ which B needs to receive. As $\overline{P_C} > \underline{P_B}$, C is able to pay that price and does not even need all of its surplus liquidity in the process. B sells all of its high value assets and receives exactly the amount of liquidity required to provide all contractually agreed repayments and interest payments to A. B remains solvent and liquid in this second scenario.

In the third scenario, B is solvent but illiquid and defaults on its debt. If $\underline{P_B} > Z$, the boundary price which B needs to receive for all of its high value assets, is an overvalued price. While C is theoretically able to pay that overvalued price with the available surplus liquidity, the fundamental price Z is the maximum price C is willing to pay. At the fair price, a liquidity premium of zero is charged.[27] C buys all of B's high value assets for the fair price Z instead of the required $\underline{P_B}$. Thereby, C does not use all of its surplus liquidity. B is forced to sell all of its high value assets, but nevertheless it is not able to collect enough liquidity, as the selling price is too low. In t=1, B is not able to repay its debt and becomes illiquid in the third scenario. The remaining low value assets, which serve as collateral in the case of default, are transferred to A. B disappears from the marketplace. The condition for illiquidity is given in (4.21).

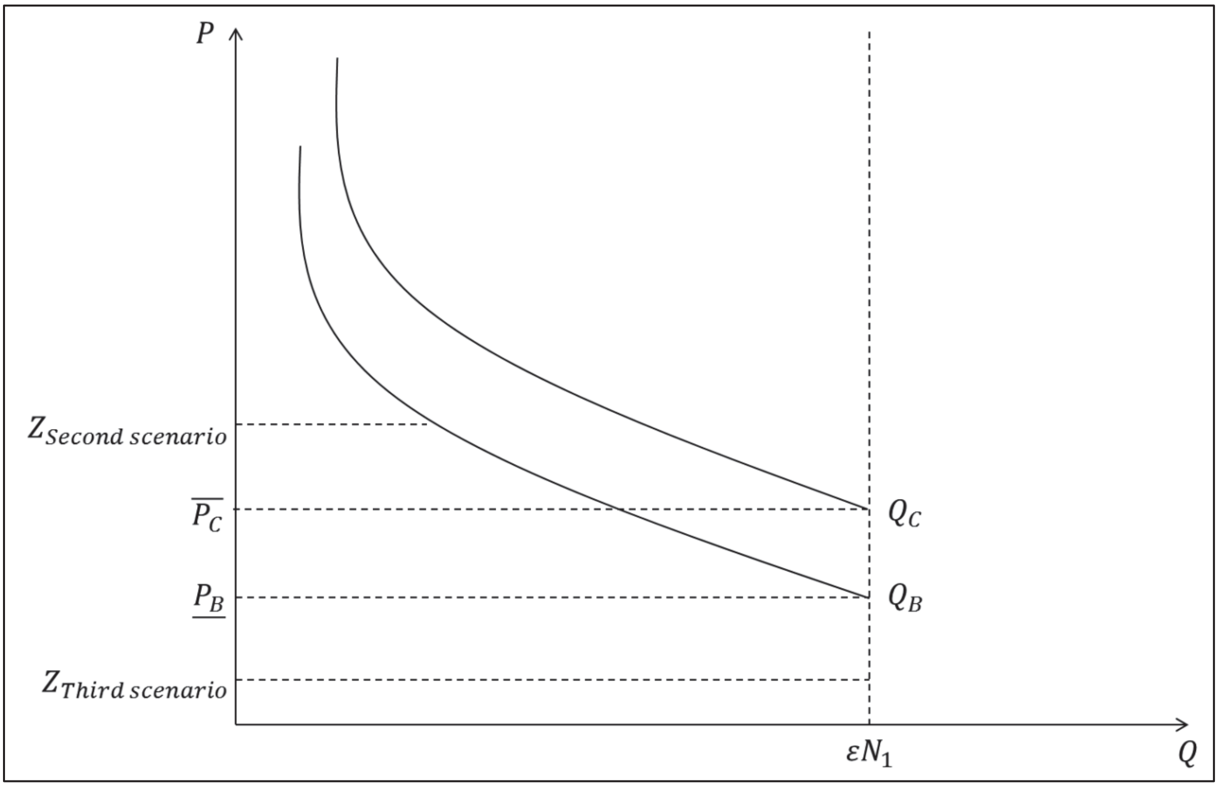
$$\underline{P_B} > Z$$

$$\Rightarrow \varepsilon < \varepsilon^{**} = \frac{\eta\delta(Z - V) - (\Omega - \Phi)}{Z - V\delta} < \eta \tag{4.21}$$

Figure 4.3 shows the asset supply and demand function. In the second scenario, the fair price of the high value asset is higher than the minimum price which B needs to receive, $\underline{P_B} < Z$. B sells all high value assets for that minimum price $\underline{P_B}$ and remains liquid. The proceeds generated from the sale of the tradable assets are sufficient to meet the repayment obligations caused by the tighter funding conditions. In the third scenario, the fair price of the high value asset is lower than the minimum price which B needs to receive, $\underline{P_B} > Z$. As C does not pay above the fundamental price Z, B needs to sell all tradable assets at a too low price and becomes illiquid. The market liquidity turns out to be insufficient to fill the liquidity gap.

[27] A positive liquidity premium makes the illiquidity problems worse.

Figure 4.3: Asset supply and demand



At this point it needs to be clarified, why B is illiquid in the third scenario. B is illiquid, if it cannot receive funds for the continuation of a project which is worth continuing.[28] If B was able to continue its business, the non-tradable low value assets could be operated, instead of transferred to A. Factoring in the inevitable mismanagement of the unlucky service provider, the proceeds from these low value assets in t=2 are $(1-\varepsilon)N_1(V-\sigma)$. If the business of B is terminated, A receives the low value assets as collateral and liquidates them. The thereof resulting liquidation value in t=2 is $(1-\varepsilon)N_1 V\rho$. If the continuation value is higher than the liquidation value, a worthwhile project of B is stopped because B lacks the required liquidity in t=1. Consequently, assuming (4.22), the third scenario can be described as illiquidity of B.

$$(1-\varepsilon)N_1(V-\sigma) > (1-\varepsilon)N_1 V\rho$$

$$\Rightarrow V(1-\rho) > \sigma \tag{4.22}$$

[28] Refer to Tirole (2010) for this formulation of illiquidity.

If the third scenario applies, B is liquidity constrained. The shortage of liquidity is triggered by B's unlucky investment in a too bad portfolio. While B's investment is also below average in scenario two, it is still good enough to meet all debt and interest repayments. This good-enough investment grade, however, is not given in the third scenario. The sudden downward shift in collateral value forces B to de-lever its position too strongly. In the second scenario, C is induced to use its surplus liquidity to support B's de-leveraging process. In the third scenario, it is more profitable for C to hoard some of its surplus liquidity. One can think of the third scenario as a severe shock. Once this shock is big enough, the liquidity redistribution from the lucky service provider C to the unlucky service provider B is not sufficient. Contractual payment requirements thus cannot be serviced by B. Subsection 4.6 shows that such a severe shock turns out to be a rare event.

4.5.2.2 Contagious effects

Subsections 4.5.2 and 4.5.2.1 outlined that a debt contract can lead to situations in which the unlucky service provider B defaults on its contractually obliged payments: The first scenario in which B is insolvent or the third scenario in which B is solvent but illiquid. The problems of B can lead to contagious pressure if the losses of B trigger a subsequent loss situation for A. The default of B, however, does not necessarily severely affect A. If B manages to service all down payments, A only sustains decreased interest revenues but no losses. Even if B also defaults on the regular repayments, the payoff from the collateral which A collects might be high enough to prevent A from losses.

The condition for B infecting A is examined in the following: Once the condition for insolvency (4.15) or illiquidity (4.21) is met, A realizes an in- and outflow of funds, which is summarized in (4.23).[29]

$$-\eta N_1(Z-V)\delta+\varepsilon N_1(Z-V\rho)-N_1V(\delta-\rho)+(2+\varepsilon)N_1\Phi+N_1\Omega \qquad (4.23)$$

Depending on ε, (4.23) is either greater or smaller than zero, where a negative value represents a loss for A. The debt contract results in a loss for A, if condition (4.24) is met.

[29] For the derivation of the flow of funds refer to Appendix D in Subsection 4.10.4.

$$\varepsilon < \varepsilon^{***} = \frac{\eta\delta(Z - V) + V(\delta - \rho) - 2\Phi - \Omega}{Z - V\rho + \Phi} < \eta \qquad (4.24)$$

The reasons for a loss of A require close attention. As the aggregate investment value does not deteriorate between the time of financing in t=0 and profit generation in t=2, additional financing needs in the intermediate period t=1 should seem to be unnecessary. Nevertheless, the aggregate supply of funds by A turns out to be insufficient to support the payment schedule of both B and C.

In t=1, the unlucky service provider faces tighter credit conditions from the funding side and is contractually obliged to repay some part of the debt capital to A. These repaid funds are immediately absorbed by the lighter credit constraint of the lucky service provider which receives those additional funds. The problem, however, is that B lacks the ability to do all required repayments. A does not receive all funds from B, but is nevertheless contractually obliged to pay out more funds to C, actually those funds which B should have repaid. In t=1, A is consequently forced to augment the outstanding debt capital as compared to t=0.

In t=2, A can use the low value assets which it received as collateral to counterbalance the additional debt pay-out. Yet these proceeds are not necessarily enough to capture the missed repayment of B. The payments of C are capped to the received credit and the interest payment. Thus A cannot profit from the fact that C has more high value assets after the trade.

Contagious pressure emerges, if the random variable ε fulfils a pair of two conditions:

i) The condition for insolvency (4.15) or the condition for illiquidity (4.21).
ii) The condition for losses of A (4.24).

As long as B is solvent and liquid, there is always full repayment for A. However, if B is insolvent or solvent and illiquid, the full repayment of all funds is not guaranteed. Offering a debt contract is nevertheless reasonable for A, as it is designed to provide expected profits of zero at minimum, as Subsection 4.5.2.3 demonstrates. Therefore it dominates the state contingent contract with its secured losses. The dominance of the debt contract emanates from its ability to adjust the problems of missing management incentives as Subsection 4.5.2.4 shows.

4.5.2.3 Participation constraints

The state contingent contract turned out to be not implementable in the presence of missing management incentives, as it generates negative expected profits for A. A debt contract is only signed by the risk neutral market participants, if it delivers expected profits of zero at minimum.

For A, participation depends on the right choice of per asset interest Φ. In the worst case, the random variable ε turns out to be zero and A realizes the highest potential losses. In the best case, both B and C make all contractual payments. A then profits from all interest payments amounting to $4N_1\Phi$. According to the pay-out scheme of A given in (4.23), the situation for A always improves with increasing Φ. A has to evaluate all probabilities of ε and has to raise the interest until $\Phi = \Phi^*$ so that the participation constraint for A given in (4.25) is fulfilled.

$$\Phi^* \rightarrow E(\mathrm{A}|\Phi,\varepsilon) = \sum_{\varepsilon=\varepsilon_{min}}^{\eta} [\text{Payoff}(4.23)(\Phi,\varepsilon)]P(\varepsilon) \geq 0 \tag{4.25}$$

In comparison to A, service providers B and C cannot influence their participation by setting the interest endogenously. The unlucky service provider incurs different losses depending on the realization of ε. Accordingly, the lucky service generates different profits.[30] Both service providers are a priori identical and have an equal chance of being the lucky or the unlucky service provider and an equal chance of losses and profits.

The expected profits of B and C depend on the probabilities of the different values for ε and the exogenously given parameters. The exogenous parameters need to be assumed to form a combination which allows expected profits of zero at minimum. This participation assumption for B and C is not very strong. In all three scenarios, rising investment return Ω both diminishes the losses for the unlucky service provider and increases the profit for the lucky

[30] For the derivation of the losses and profits refer to Appendix D in Subsection 4.10.4.

service provider. Assuming that the participation constraint for B and C are fulfilled therefore just means assuming a sufficiently high investment return Ω.

4.5.2.4 Adjustment for missing management incentives

Why should A offer a collateralized short-term debt contract? In the basic setting, A can provide credit in t=0 and B is either solvent or insolvent according to (4.15). No short-term readjustments in t=1 are necessary. Yet, in a short-term debt contract the credit conditions are directly related to the development of the collateral value. Because of the renegotiations of the credit conditions in t=1, a liquidity requirement for B emerges. This poses a new threat of illiquidity. Comparing the insolvency condition (4.15) with the illiquidity condition (4.21), it can additionally be recognized that the condition for illiquidity is weaker than the condition for insolvency. Illiquidity is therefore more impending, as the random variable ε does not need to drop as much as in the insolvency scenario. Yet it is nevertheless reasonable for A to rely on this contractual agreement for the following reason:

With the development of the investment projects in t=1, it becomes clear if B is solvent. At the same time, the managers of B recognize that they work for the company which will not have any increases but losses in equity. As a consequence, performance payment is not possible anymore. A knows that due to the missing management incentive, all of B's assets do not realize their expected payoff in t=2, but will suffer a discount of σ instead. In addition, B's assets do not generate a return of Ω. Due to that knowledge, A is only willing to provide as much debt in t=1, that B's proceeds in t=2 are sufficient to make all repayments and interest payments even if the management of B behaves badly.

By only financing a fraction δ of the investments in t=0, A can secure that B is able to deliver all contractual payments in t=2. As long as the unlucky service provider did not default in t=1 and did not disappear from the market place, bad management cannot affect the business of A anymore. A's problem arising from missing management incentives is healed by the debt contract, as long as the fraction δ is determined accurately.[31] Besides protecting against the problems caused by missing management incentives, a debt contract renders losses for A and

[31] For the derivation of δ refer to Appendix E in Subsection 4.10.5.

hence contagion extremely unlikely. As, however, very unlikely events still occur with positive probability, the security of the debt contract turns out to be deceptive.

4.6 Likelihood of contagion

The insolvency or illiquidity problems of the unlucky service provider B spread out if they lead to losses for the credit provider A. Losses for A in a debt contract only arise if one of the condition sets (4.15) and (4.24) or (4.21) and (4.24) is met. As the condition for insolvency (4.15) implies the condition for illiquidity (4.21), it is sufficient to examine under which circumstances (4.21) and (4.24) are simultaneously fulfilled. For these two conditions the random variable ε must be smaller than the boundaries ε^{**} and ε^{***}.

In order to evaluate the probability of a low enough ε, its distribution needs to be assessed. In t=0, there is a pool of a limited number of investment projects N_0, from which B and C draw their N_1 investment projects without replacement. Within the N_0 projects of the entire portfolio, there are M high value projects and $(N_0 - M)$ low value projects. M is exogenously known, as $\eta = M/N_0 = M/2N_1$.

From the N_1 projects, the unlucky provider draws Ψ high value projects and $(N_1 - \Psi)$ low value projects. This Ψ follows a hyper geometric distribution, as there is no replacement of the projects. ε represents the fraction of high value assets in the unlucky service provider's portfolio, consequently $\varepsilon = \Psi/N_1$. It follows that ε is a hyper geometrically distributed random variable divided by a constant. Consequently, ε itself is also hyper geometrically distributed.

The probability of the loss conditions (4.21) and (4.24) can be evaluated using the hyper geometric distribution. With increasing N_1, the hyper geometric converges to a binomial distribution. Accordingly, the number of high value projects Ψ which B draws, converges exactly to half of the M high value projects in N_0, i.e. to ηN_1 and ε converges to η. Given the fact that N_0 is a large number, the fulfilment of both conditions becomes extremely improbable. With ε converging to η, the small boundaries ε^{**} and ε^{***} are unlikely to reach. Given the fact, however, that N_0 is finite, leaves a small probability for that very event. Contagious pressure for A is highly unlikely, but can occur.

It is reasonable for A to offer a debt contract instead of a state contingent contract, because it better safeguards the funds. Yet, this security is deceptive, as in some situations, a debt contract can lead to losses for A. If A's losses are substantial and there is no protection against this unlikely risk, serious contagion issues arise. As this describes a very rare event, the financial market situation in 2007 is suitably characterized. Markets' functioning is not distracted in normal times. However, there exists a threat which can trigger huge disorder, if the small probability for contagion is neglected.

4.7 Aggregate shocks

In all results derived so far, an idiosyncratic shock is assumed. The unlucky service provider suffers decreased funding liquidity because of a sudden reduction in the investment value. Subsequently the market liquidity of tradable assets is either sufficient or insufficient to fill the emerging liquidity gap. Existing surplus liquidity of the lucky service provider is crucial for sufficient market liquidity.

An idiosyncratic shock falls short in describing the financial crisis of 2007 perfectly. Besides a redistribution of investment value, a reduction of the aggregated investment volume burdened the financial markets. The model can easily be extended by an aggregate shock which hits both service providers simultaneously. A simple way to show this is to redefine the investment return Ω. With an idiosyncratic shock, it was assumed that the per period and per asset investment return is larger than the respective interest, $\Omega > \Phi$. Dropping this assumption allows for an aggregate shock. If an unexpected aggregate shock hits the overall economy in t=1, the return decreases so that $\Omega < \Phi$.

With Ω falling below Φ, B is insolvent or illiquid for sure. If condition (4.15) is fulfilled, B is insolvent. If B is solvent, the minimum boundary price it needs to receive for its assets (4.19) in order to meet its liquidity requirement is always higher than the maximum price C can afford (4.20), $\underline{P_B} > \overline{P_C}$. The aggregate supply of liquidity is smaller than the aggregate demand. A lack of markets for the high value assets of B causes inevitable illiquidity. With assured insolvency or illiquidity of B, only A's loss condition (4.24) needs to be fulfilled in order to allow for contagious pressure. Meeting this condition becomes more likely, as the boundary ε^{***} increases with falling Ω. The threat that B's financial problems infect A becomes more acute due to the aggregate shock.

4.8 Policy recommendations

If A is not able to contractually protect against contagion, political measures need to be taken in order to safeguard the economy of problems arising from insolvency or illiquidity of A. The danger of financial market distress spreading to the economy is to be averted. Depending on the size of A's losses, a costly bailout can become necessary ex post. In order to avoid a bailout situation, ex ante measures need to be considered.

By merging B and C to one big entity, the government can simply guarantee that no unlucky service provider exists at all. This new company can invest in all N_0 projects and thus exactly in the average portfolio. Losses emerging from the redistribution of investment value from the unlucky to the lucky service provider are not possible anymore. Yet, a monopoly is created, giving rise to other forms of market distortions. Other measures, however, prove to be helpful.

4.8.1 Higher equity capital requirements

Losses for A only occur, if the unlucky service provider draws some Ψ allowing for ε being smaller than both the boundaries given in (4.21) and (4.24). With large N_0, ε converges to η. Consequently, the smaller ε^{**} and ε^{***} are, the less likely it is to draw a situation resulting in a loss for A.

Recognizing the influence of the exogenously given parameters on the default and contagion probability can lead to helpful policy recommendations. Only the margin δ is a factor which is controlled by the government. The smaller the margin parameter δ, the fewer debt capital B and C are allowed to use in order to finance the projects. With decreasing δ, contagion become less likely, as ε^{***} falls. With higher equity capital requirements, losses of A are generated more rarely.

Raising equity capital requirements helps stabilizing the financial system. Once B defaults, the high value projects are redistributed from the unlucky to the lucky service provider. This redistribution is only advantageous for C. Though A receives all proceeds from the trade of the high value assets and the remaining low value assets as collateral, these two sources of liquidity are not always enough. The problem lies in the fact that B lost too little equity capital in comparison to the equity gains of C. Consequently, also A needs to incur some losses. If, however, the losses of B are increased by augmenting the equity capital put at risk, A is not forced to make own losses in order to capture the gains of C.

4.8.2 Governmental provision of outside liquidity

Another potential measure to stabilize the financial system is an intermediate provision of governmental funds in t=1. If B is illiquid in t=1, A receives the low value assets as collateral and liquidates them with the discount ρ. Due to that discount, it might be better if the assets were operated by B for the second period. But also if B operated the assets, value reductions caused by missing management incentives would be generated.

It is consequently necessary to compare the liquidation value with the proceeds a bad management generates. If it was better to allow for a continuation of B's business, government intervention would be useful. By providing enough outside liquidity in t=1, a default of B can be averted and remaining non-tradable low value assets can be operated by B until t=2. In t=2, the losses from this governmental injection of liquidity are rolled over to A, so that the government is not responsible to carry the losses. The government needs to assess if the aggregate results for A are better if B becomes illiquid or not. If the errors of a bad management are preferable to the discount due to limited pledgeability, it is reasonable to provide outside liquidity. As A and B also profit from that liquidity provision, they reasonably accept the intervention.[32]

4.9 Conclusion

The model shows that unlucky investment decisions can trigger insolvency or illiquidity of the affected market participant. These financial problems in turn can trigger contagious effects, which threaten other market participants. If not decently accounted for, contagion can hamper the functioning of the financial system. While efficient contracts theoretically exist,

[32] For the derivation of the condition favoring outside liquidity provision refer to Appendix F in Subsection 4.10.6.

they are ruled out once the additional friction of missing incentive structures disturbs the markets. Under such circumstances, debt contracts can prevent that financial problems of one service provider spread to another service provider in normal times. Heavy shocks, however, allow for contagious pressures arising from the debt contract in very rare cases. While normally functioning smoothly, the financial system can get into a severe predicament in such occasions. The debt contract therefore only provides a deceptive security.

As recent history has shown that preparation for rare but catastrophic events is limited, governmental actions need to be put in place in order to force for necessary preparation. In order to avoid ex post bailouts, ex ante regulation needs to be implemented. A higher degree of equity capital financing decreases the likelihood of spreading losses. Governmental liquidity injections are useful in some occasions. Relying on a prudent combination of equity capital requirements and provision of outside liquidity, leads to preferable outcomes for the financial system. The measures guarantee that only investors directly hit by the shock suffer the worst losses. The investor’s financiers remain less affected. The threat of contagion infecting the financial markets as a whole is alleviated.

4.10 Appendix

4.10.1 Appendix A: $\varepsilon - \gamma -$boundaries

The $\varepsilon - \gamma -$combinations have natural boundaries. The worst draw B can realize is receiving zero high value projects. As a consequence, $\varepsilon \geq 0$. The best draw C can realize, is receiving only high value projects. As a consequence, $\gamma \leq 1$. As from (4.6) $\gamma = 2\eta - \varepsilon$, this yields $\varepsilon \geq 2\eta - 1$. In total the two inequality conditions of ε yield (A.4.1).

$$\varepsilon_{min} = \max\{0; 2\eta - 1\} \tag{A.4.1}$$

Solving for γ, $\varepsilon \geq 0$ and $\varepsilon = 2\eta - \gamma$ yields $\gamma \leq 2\eta$. Both inequalities of γ yield (A.4.2).

$$\gamma_{max} = \min\{1; 2\eta\} \tag{A.4.2}$$

4.10.2 Appendix B: Asset supply function

The liquidity requirement of B is the amount of funds which B is contractually obliged to pay to A in t=1. This amount consists of three parts: First, because of the decreased investment value, A grants less credit to B as compared to t=0. The difference between the credit volume in t=0 and in t=1 is the repayment obligation. Second, A charges interest for the first period of credit provision. This interest amounts to Φ per financed asset. Third, B has a source of liquidity because it receives a return amounting to Ω per financed asset. The first part is captured in the first term of (B.4.1), the second and the third part in the second term.

$$\left[(\eta N_1 Z + (1-\eta)N_1 V)\delta - \left(N_{2,B}(P)Z + (1-\varepsilon)N_1 V\right)\delta\right] - N_1(\Omega - \Phi) \quad \text{(B.4.1)}$$

$(1-\varepsilon)N_1$ is B's amount of low value assets. Those assets cannot be traded for liquidity. $N_{2,B}(P)$ is the amount of high value assets B possesses after trade took place in t=1. As the number of assets B needs to sell in order to remain liquid depends on the asset price, also the amount of high value assets B possesses after trade depends on the price P. This amount of assets influences the collateral value.

After the draw in t=0, B has εN_1 tradable high value assets. As B needs liquidity, it trades those assets. But by selling assets, the portfolio value and thereby the collateral value decreases further. The decreasing collateral value again reduces the funds A provides in t=1. There is consequently further amplification of the liquidity shortage. The liquidity requirement of B divided by the asset price determines how many assets need to be sold. This yields the asset supply function (B.4.2)

$$Q_B\left(N_{2,B}(P)\right) =$$
$$= \frac{(\eta N_1 Z + (1-\eta)N_1 V)\delta - (1-\varepsilon)N_1 V\delta - N_1(\Omega - \Phi)}{P} - N_{2,B}(P)\frac{Z\delta}{P} \quad \text{(B.4.2)}$$

Now it is problematic, that the liquidity requirement of B also depends on the number of B's high value assets $N_{2,B}(P)$ after t=1. Consequently, the trading behavior of B also influences the liquidity need. The asset supply function should determine the trading behavior of B and therefore it is not convenient if this function itself is influenced by the trading behavior. It is the goal to find an asset supply function of B, which is only dependent on P and independent of the number of B's high value assets after trade.

Conveniently, there is another way to express the same asset supply function in dependence of $N_{2,B}(P)$. Asset supply is the difference of high value assets in t=0 and after trade in t=1. If this difference (B.4.3) is positive, B sold assets, if it is negative, B bought assets.

$$Q_B\left(N_{2,B}(P)\right) = \varepsilon N_1 - N_{2,B}(P) \tag{B.4.3}$$

(B.4.2) and (B.4.3) can be combined to find expression (B.4.4) for $N_{2,B}(P)$.

$$\varepsilon N_1 - N_{2,B}(P) = \frac{(\eta N_1 Z + (1-\eta)N_1 V)\delta - (1-\varepsilon)N_1 V\delta - N_1(\Omega - \Phi)}{P} - N_{2,B}(P)\frac{Z\delta}{P}$$

$$\Rightarrow N_{2,B}(P) = \frac{N_1[\varepsilon P - \eta Z\delta - (1-\eta)V\delta + (1-\varepsilon)V\delta] + N_1(\Omega - \Phi)}{P - Z\delta} \tag{B.4.4}$$

(B.4.4) needs to be used in (B.4.3) to arrive at the asset supply function of (4.17).[33]

[33] If $P < Z\delta$, the asset supply function (4.17) turns into a demand function. The asset price is too low for B to remain liquid when selling assets. B's only chance to remain liquid is to buy undervalued assets, which would grant better financing conditions due to their higher expected value. This demand function can be neglected, as it is straightforward that no market participant would sell at such an undervalued price. Accordingly, if $P < Z\delta$, the asset demand function (4.18) turns into a supply function which can also be neglected. C is not in liquidity problems and therefore does not sell assets at an undervalued price.

4.10.3 Appendix C: Limited pledgeability

It is assumed that A lacks the specialization in the investment fields of B and C. For A, it is therefore not profitable to engage in the trade of assets between B and C. The discount factor ρ, which A has to sustain if operating the assets, is too high. In particular this assumption means that even if the trading price between B and C falls to its lowest value, this value is still too high for A to enter in that trade.

The lowest price for which C buys the high value assets is B's minimum boundary price $\underline{P_B}$ given in (4.19) in the second scenario and the fair value Z in the third scenario. Because of the discount factor ρ, the fair price Z is always too high for A. B's minimum boundary price $\underline{P_B}$ decreases with increasing ε. The highest value ε can take is its convergence value η. With $\varepsilon = \eta$, the boundary price thus reaches its minimum.

If A buys a high value asset, A liquidates it and realizes a value of $Z\rho$. If trade is assumed to be unreasonable for A, the liquidation value needs to be smaller than the minimum trade price between B and C as shown in (C.4.1).

$$\underline{P_B}(\varepsilon = \eta) = \frac{\eta\delta(Z - V) - (\Omega - \Phi)}{\eta} + V\delta > Z\rho$$

$$\Rightarrow \Phi > \eta Z(\rho - \delta) + \Omega \qquad \text{(C.4.1)}$$

The endogenously chosen interest rate Φ needs to be big enough. Yet, this is not possible as long as $\rho > \delta$ and $\Phi < \Omega$. This means that A theoretically could engage in B and C's trade in the second scenario. In this scenario, however, B is solvent and liquid anyways and no problems for A arise. Contagious effects only exist in scenarios in which the unlucky service provider is insolvent or illiquid. In these scenarios, B receives a price of Z for its high value assets. So even if condition (C.4.1) is not met and A could engage in the trade once B is liquid, A cannot engage in the trade once B is insolvent or illiquid, because $Z\rho < Z$. All results thus hold if one assumes limited pledgeability for A with $\rho < 1$.

4.10.4 Appendix D: Flow of funds

The flow of funds can be derived for all three scenarios in which the unlucky service provider is insolvent, solvent and liquid or solvent but illiquid. For the first and the third scenario, insolvency and illiquidity, the flow of funds is identical for the following reasons:

In the third scenario, in which B is illiquid, it sells all high value assets to C at the fair price Z. A receives all proceeds from the trade between B and C and the first period return generated by B. As B nevertheless defaults on its payments, the non-tradable low value assets are transferred to A as collateral. B loses all invested equity and disappears from the market place. C gains from the redistribution of investment value. A either gains or loses, depending on the contagion condition (4.24).

In the first scenario, in which B is insolvent, A receives B's first period return and all high and low value assets as collateral. Due to the limited pledgeability, A is not able to operate these assets properly. A is stuck on the low value assets, because these are non-tradable. The high value assets, however, are tradable and A is better off when selling those to C. As the insolvency condition (4.15) is met, the illiquidity condition (4.21) is implied and therefore $\overline{P_C} > \underline{P_B} > Z$. C has consequently enough surplus liquidity to buy all of B's high value assets from A for the fair price Z.[34] Thus, also in insolvency B loses all equity, C receives all of B's high value assets for the price Z and A receives an identical payoff as in the illiquidity scenario. The first and third scenario are identical. The flow of funds only needs to be derived for the first and third scenario on the one hand and for the second scenario on the other hand.

In the first and in the third scenario, A receives the following flow of funds: In t=0, A pays out credit to B and C as given in (4.16). In t=1, A receives all proceeds from the trade of B's εN_1 high value assets and B's first period returns, represented by the first two terms in (D.4.1). Additionally, A pays out more debt to C because of C's improved collateral value, represented by the third term in (D.4.1). Finally, A receives C's first period interest payments, represented by the fourth term in (D.4.1).

[34] A positive liquidity premium generates redistribution between A and C. The overall result of C improves and the result of A deteriorates by the same amount. With more competition in the sector of financial service providers, C is not able to charge a liquidity premium.

$$\varepsilon N_1 Z + N_1 \Omega + \left[(\eta N_1 Z + (1-\eta) N_1 V)\delta - \left((\varepsilon+\gamma) N_1 Z + (1-\gamma) N_1 V\right)\delta\right] + N_1 \Phi \quad \text{(D.4.1)}$$

In t=2, A receives discounted proceeds from the low value assets which it received as collateral from B, represented by the first term of (D.4.2). In addition, A receives full repayment of C's outstanding debt and C's interest payments for all invested assets of the second period. Those assets consist of N_1 initially acquired assets and the εN_1 assets bought in t=1.

$$(1-\varepsilon) N_1 V \rho + \left((\varepsilon+\gamma) N_1 Z + (1-\gamma) N_1 V\right)\delta + N_1 \Phi (1+\varepsilon) \quad \text{(D.4.2)}$$

Aggregating (4.16), (D.4.1) and (D.4.2) lead to a total payoff for A as given in (4.23).

Due to the default, B loses all invested equity capital, leading to losses of (D.4.3).

$$-(\eta N_1 Z + (1-\eta) N_1 V)(1-\delta) \quad \text{(D.4.3)}$$

The lucky service provider C has the same equity pay-out in t=0, represented by the first term of (D.4.4). In t=1, C receives more debt capital because of better funding liquidity. In addition, C generates first period returns and has to pay first period interest per invested asset.

Both sources of liquidity are immediately used to buy all high value assets of B. Not all surplus liquidity is needed to buy the high value assets, as C pays the price Z which is smaller than the maximum boundary price $\overline{P_C}$, which it could potentially afford. Using the maximum boundary price (4.20), the net inflow of liquidity in t=1 can be derived. This surplus liquidity is represented by the second term of (D.4.4).

In t=2, C receives the proceeds from all $(\varepsilon+\gamma) N_1$ high value assets and its own $(1-\gamma) N_1$ low value assets. From these proceeds, the debt capital is repaid, as given in the third term of (D.4.4). Finally, for all the invested assets, second period returns are generated and second period interest is paid, as indicated in the fourth term of (D.4.4)

$$-(\eta N_1 Z + (1-\eta)N_1 V)(1-\delta) + \left(\overline{P_C} - Z\right)\varepsilon N_1$$
$$+[(\varepsilon+\gamma)N_1 Z + (1-\gamma)N_1 V](1-\delta) + (1+\varepsilon)N_1(\Omega - \Phi)$$
$$= (\eta - \varepsilon)N_1(Z - V) + (2+\varepsilon)N_1(\Omega - \Phi) \quad \text{(D. 4.4)}$$

Summing up the results of A (4.23), B (D.4.3) and C (D.4.4) yields an aggregate result for the first and the third scenario as given in (D.4.5).

$$-(1-\varepsilon)N_1 V(1-\rho) + (3+\varepsilon)N_1\Omega \quad \text{(D. 4.5)}$$

The aggregate flow of funds is accurate. For all adequately operated assets, there are returns of Ω per period. Only the $(1-\varepsilon)N_1$ non-tradable low value assets, which A operates in the second period, do not generate a return in t=2. Furthermore, those low value assets suffer from wasted value caused by A's limited pledgeability.

In the second scenario, the flow of funds is different. The debt contract ensures that in t=2, A receives full repayment of all funds and full interest payment. Gains according to (D.4.6) are generated.

$$4N_1\Phi \quad \text{(D. 4.6)}$$

In t=0, the unlucky service provider B has an equity pay-out given in the first term of (D.4.7). In t=1, all high value assets are sold and the resulting liquidity is used to make down payments and interest payments to A. In t=2, the non-tradable low value assets generate proceeds, however, diminished by the factor σ due to the mismanagement, as shown in the second term of (D.4.7). Those proceeds are sufficient to repay the remaining debt capital and to service interest obligations, as the third and the fourth term of (D.4.7) demonstrate. In the worst case, B loses all equity and the total payoff (D.4.7) is zero.

$$-(\eta N_1 Z + (1-\eta)N_1 V)(1-\delta) + (1-\varepsilon)N_1(V-\sigma) - (1-\varepsilon)N_1 V\delta - (1-\varepsilon)N_1\Phi$$
$$= -(\eta N_1 Z - (\eta-\varepsilon)N_1 V)(1-\delta) - (1-\varepsilon)N_1(\sigma + \Phi) \quad \text{(D. 4.7)}$$

For the lucky service provider C, the result is similar as described in (D.4.4). The only difference is that C buys the high value assets of B at the lower price $\underline{P_B}$, the minimum boundary price of B. Only the second term of (D.4.8) changes as compared to (D.4.4). Using (4.19) and (4.20), this new term can be derived:

$$\begin{aligned} &-(\eta N_1 Z + (1-\eta) N_1 V)(1-\delta) + \left(\overline{P_C} - \underline{P_B}\right) \varepsilon N_1 \\ &+[(\varepsilon + \gamma) N_1 Z + (1-\gamma) N_1 V](1-\delta) + (1+\varepsilon) N_1 (\Omega - \Phi) \\ &= (\eta N_1 Z - (\eta - \varepsilon) N_1 V)(1-\delta) + (3+\varepsilon) N_1 (\Omega - \Phi) \end{aligned} \tag{D.4.8}$$

Summing up the results of A (D.4.6), B (D.4.7) and C (D.4.8) yields an aggregate result for the second scenario as given in (D.4.9).

$$-(1-\varepsilon) N_1 \sigma + (3+\varepsilon) N_1 \Omega \tag{D.4.9}$$

The aggregate flow of funds is again accurate. Returns are identical to (D.4.5). Furthermore, the $(1-\varepsilon)N_1$ non-tradable low value assets of B are operated by a bad management in the second period. Therefore, these assets sustain a value reduction of σ in t=2.

4.10.5 Appendix E: Derivation of δ

The value of δ is to be chosen in order to make the missing management incentives irrelevant for A. In t=2, the minimum possible payoffs of B must be enough to fully cover all repayments and interest payments.

The left hand side of (E.4.1) describes B's proceeds in t=2, given that the management misbehaves. The first term of the right hand side represents the debt capital A provided in t=1, the second term the interest which A charges per financed asset.

$$N_{2,B}(P)(Z-\sigma)+(1-\varepsilon)N_1(V-\sigma)$$
$$=\left[N_{2,B}(P)Z+(1-\varepsilon)N_1V\right]\delta+\left[N_{2,B}(P)+(1-\varepsilon)N_1\right]\Phi \qquad (\mathrm{E}.4.1)$$

In the worst case, B has to sell all of its high value assets and $N_{2,B}(P)=0$. Then (E.4.1) can be solved for that δ which guarantees full payment for A, even if the management of B acts badly and additionally the worst case becomes reality (E.4.2).

$$\delta=\frac{V-\sigma-\Phi}{V} \qquad (\mathrm{E}.4.2)$$

For $\Phi<V-\sigma$ this takes a positive value.

4.10.6 Appendix F: Outside liquidity

In order to circumvent illiquidity of B in t=1, the government can provide missing liquidity in the third scenario. Without outside liquidity, B receives a price of Z for its εN_1 high value assets instead of the required price $\underline{P_B}$ given in (4.19). For supporting B, the government has to pay the difference, as given in (F.4.1).

$$-\left(\underline{P_B} - Z\right)\varepsilon N_1 = -\eta\delta N_1(Z - V) - \varepsilon\delta N_1 V + \varepsilon N_1 Z + N_1(\Omega - \Phi) \qquad \text{(F.4.1)}$$

As a consequence, B is not illiquid and can operate the remaining low value assets until t=2. Because of the missing management incentives, only proceeds represented by the first term of (F.4.2.) are generated. After repaying debt and interest to A, described by the second and the third term of (F.4.2), B receives the following proceeds, which can be used to reimburse the government:

$$(1-\varepsilon)N_1(V-\sigma) - (1-\varepsilon)N_1 V\delta - (1-\varepsilon)N_1\Phi \qquad \text{(F.4.2)}$$

In total, (F.4.1) and (F.4.2) yield losses for the government amounting to (F.4.3). These losses can be rolled over to A.

$$-\eta\delta N_1(Z-V) + \varepsilon N_1(Z-V) - N_1 V(1-\delta) - (1-\varepsilon)N_1\sigma - (2-\varepsilon)N_1\Phi + N_1\Omega \qquad \text{(F.4.3)}$$

If the government does not intervene, the losses for A amount to (4.23). Comparing (4.23) with (F.4.3), it can be shown that governmental provision of outside liquidity mitigates the contagion problem, if condition (F.4.4) is fulfilled.

$$V(1-\rho) - \sigma - 4\Phi > \varepsilon(V(1-\rho) - \sigma) \qquad \text{(F.4.4)}$$

4.10.7 Appendix G: Generalization of results

All results are derived for an example with one debt capital provider A and two debt capital consumers B and C. Qualitatively, the results also hold if there is more competition in both groups of market participants.

For the providers of debt capital, the fulfillment of the participation constraint (4.25) is crucial. The interest Φ has to be chosen adequately, so that expected profits of zero are guaranteed at minimum. If there are more debt capital providers, they compete for consumers by setting this interest rate. While one provider of debt capital has the possibility to offer an interest rate which allows for positive expected profits, this becomes impossible if there are more identical providers. Condition (4.25) is still fulfilled for all of them, but the charged interest rate will shrink to a value Φ^* which exactly allows expected profits of zero. If a single debt capital provider deviated from that interest rate, either the participation constraint is not fulfilled anymore ($\Phi < \Phi^*$), or all consumers are lost to the cheaper competitors ($\Phi > \Phi^*$). More debt capital providers limit potential profits of A. The consumers of debt capital gain from that competition and insolvency or illiquidity becomes less likely. Quantitatively, the results for all market participants change. Qualitatively, however, the contagion risk cannot be averted.

For the consumers of debt capital, more competition also leads to qualitatively identical results. Without loss of generality, an example with three financial service providers of this group is considered. If there are three identical service providers, they split the available assets into three equal parts. In t=1, it either turns out that one invested above and two below average, or that two invested above and one below average.

In the first case, there is again no competition for the sale of high value assets. The single lucky service provider can charge a price derived from the same scheme as discussed in Subsection 4.5.2.1, the two unlucky ones turn out to be insolvent, illiquid or liquid. The results only change quantitatively, because now either one or two service providers can become insolvent or illiquid.

In the second case, two service providers compete for the high value assets of the single unlucky one. The aggregate surplus liquidity of the two lucky service providers is greater than the demand of the unlucky service provider.

As long as the unlucky service provider is liquid and there is only one lucky service provider, the unlucky one receives its minimum boundary price for its high value assets, because the single provider of liquidity is able to charge a liquidity premium. This changes if there is competition, because the two lucky service providers compete for the assets by offering higher prices until the fair value Z is reached. More competition for the high value assets therefore only reduces the potential profits of the two providers of liquidity. They cannot charge a liquidity premium and the unlucky service provider profits thereof. Yet, if the unlucky service provider is insolvent or illiquid, all assets are already traded for the fair price Z and therefore with a liquidity premium of zero. Also with competition for the liquidity providers, the selling price does not exceed the fair value Z. Insolvency and illiquidity cannot be averted. Also the contagion risk persists.

Competition in either of the two types of market participants leads to redistribution between those. Quantitatively, the derived results therefore change. The threat of financial problems spreading through the system is, however, not averted. The probability of contagion is different, but it remains nonzero. Qualitatively, competition cannot solve the problems discussed.

Bibliography

Abad, P., Chuliá, H., Gómez-Puig, M., 2010. EMU and European government bond market integration. *Journal of Banking & Finance*, 34, 2851-2860.

Adjaouté, K., Danthine, J.-P., 2003. European financial integration and equity returns: A theory-based assessment, in: Gaspar, V., Hartmann, P., Sleijpen, O., (Eds.), The transformation of the European financial system. ECB, Frankfurt on the Main, 186-245.

Afonso, A., Furceri, D., Gomes, P., 2012. Sovereign credit ratings and financial market linkages: Application to European data. *Journal of International Money and Finance*, 31, 606-638.

Allen, F., Gale, D., 2005. From cash-in-the-market pricing to financial fragility. *Journal of the European Economic Association*, 3, 535-546.

Arezki, R., Candelon, B., Sy, A., 2011. Sovereign rating news and financial markets spillovers: Evidence from the European debt crisis. IMF Working Paper Series, 11/68.

Arghyrou, M.G., Kontonikas, A., 2012. The EMU sovereign-debt crisis: Fundamentals, expectations and contagion. *Journal of International Financial Markets, Institutions and Money*, 22, 658-677.

Arghyrou, M.G., Tsoukalas, J.D., 2011. The Greek debt crisis: Likely causes, mechanics and outcomes. *The World Economy*, 34, 173-191.

Baele, L., Ferrando, A., Hördahl, P., Krylova, E., Monnet, C., 2004. Measuring financial integration in the euro area. ECB Occasional Paper Series, 14.

Benmelech, E., Bergman, N., 2010. Credit traps. *American Economic Review*, 102, 3004-3032.

Bernoth, K., von Hagen, J., Schuknecht, L., 2012. Sovereign risk premia in the European government bond market. *Journal of International Money and Finance*, 31, 975-995.

Bertero, E., Mayer, C., 1990. Structure and performance: Global interdependence of stock markets around the crash of October 1987. *European Economic Review*, 34, 1155-1180.

Bindseil, U., Modery, W., 2011. Ansteckungsgefahren im Eurogebiet und die Rettungsmaßnahmen des Frühling 2010. *Perspektiven der Wirtschaftspolitik*, 12, 215-241.

Blanco, R., 2002. Euro area government securities market: Recent developments and implications for market functioning, in: Market functioning and central bank policy. BIS, Basel, 65-85.

Bollerslev, T., 1990. Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH model. *Review of Economics and Statistics*, 72, 498-505.

Boyer, B.H., Gibson, M.S., Loretan, M., 1997. Pitfalls in tests for changes in correlations. International Finance Discussion Paper Series, 597R, Federal Reserve Board.

Brunnermeier, M., Pedersen, L., 2009. Market liquidity and funding liquidity. *Review of Financial Studies*, 22, 2201-2238.

Caballero, R., Krishnamurthy, A., 2001. International and domestic collateral constraints in a model of emerging market crises. *Journal of Monetary Economics*, 48, 513-548.

Caporale, G.M., Cipollini, A., Spagnolo, N., 2005. Testing for contagion: A conditional correlation analysis. *Journal of Empirical Finance*, 12, 476-489.

Cappiello, L., Gérard, B., Kadareja, A., Manganelli, S., 2006a. Financial integration of new EU member states. ECB Working Paper Series, 683.

Cappiello, L., Hordahl, P., Kadareja, A., Manganelli, S., 2006b. The impact of the euro on financial markets. ECB Working Paper Series, 598.

Chiang, T.C., Jeon, B.N., Li, H., 2007. Dynamic correlation analysis of financial contagion: Evidence from Asian markets. *Journal of International Money and Finance*, 26, 1206-1228.

Christiansen, C., 2000. Macroeconomic announcement effects on the covariance structure of government bond returns. *Journal of Empirical Finance*, 7, 479-507.

Codogno, L., Favero, C., Missale, A., 2003. Yield spreads on EMU government bonds. *Economic Policy*, 18, 503-532.

Corsetti, G., Pericoli, M., Sbracia, M., 2005. Some contagion, some interdependence: More pitfalls in tests of financial contagion. *Journal of International Money and Finance,* 24, 1177-1199.

Corsetti, G., Pericoli, M., Sbracia, M., 2011. Correlation analysis of financial contagion, in: Kolb, R.W., (Ed.), Financial contagion: The viral threat to the wealth of nations. Wiley, New York, 11-20.

Côté, D., Graham, C., 2004. Convergence of government bond yields in the euro zone: The role of policy harmonization. Bank of Canada Working Paper Series, 04-23.

Dang, T.V., Gorton, G., Holmström, B., 2012. Ignorance, debt and financial crises. Mimeo.

De Bandt, O., Hartmann, P., 2002. Systemic risk in banking: A survey, in: Goodhart C., Illing, G., (Eds.), Financial crisis, contagion and the lender of last resort: A reader. Oxford University Press, Oxford, 249-298.

De Santis, R.A., 2012. The euro area sovereign debt crisis: Safe haven, credit rating agencies and the spread of the fever from Greece, Ireland and Portugal. ECB Working Paper Series, 1419.

Delors, J., Committee for the Study of Economic and Monetary Union, 1989. Report on economic and monetary union in the European Community, first ed., Office for Official Publications of the European Communities, Luxembourg.

Diamond, D., Rajan, R., 2011. Fear of fire sales, illiquidity seeking, and credit freezes. *Quarterly Journal of Economics*, 126, 557-591.

Dungey, M., Fry, R.A., Gonzalez-Hermosillo, B., Martin, V.L., 2007. Contagion in global equity markets in 1998: The effects of the Russian and LTCM crises. *North American Journal of Finance and Economics*, 18, 155-174.

Dungey, M., Fry, R.A., González-Hermosillo, B., Martin, V.L., 2010. Transmission of financial crises and contagion: A latent factor approach, first ed., Oxford University Press, Oxford.

Dungey, M., Zhumabekova, D., 2001. Testing for contagion using correlations: Some words of caution. Pacific Basin Working Paper Series, PB01-09, Federal Reserve Bank of San Francisco.

European Central Bank, 2012. Financial Stability Review. June 2012.

Ehrmann, M., Fratzscher, M., Güürkaynak, R.S., Swanson, E.T., 2011. Convergence and anchoring of yield curves in the euro area. *Review of Economics and Statistics*, 93, 350-364.

Eichengreen, B., Rose, A.K., Wyplosz, C., 1996. Contagious currency crises. NBER Working Paper Series, w5681.

Engle, R.F., 2002. Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business and Economic Statistics*, 20, 339-350.

Engle, R.F., Sheppard, K., 2001. Theoretical and empirical properties of dynamic conditional correlation multivariate GARCH. NBER Working Paper Series, w8554.

Favero, C., Pagano, M., von Thadden, E.-L., 2010. How does liquidity affect government bond yields? *Journal of Financial and Quantitative Analysis*, 45, 107-134.

Forbes, K., 2012. The "Big C": Identifying contagion. NBER Working Paper Series, w18465.

Forbes, K, Rigobon, R., 2001. Contagion in Latin America: Definitions, measurement, and policy implications. *Economia*, 1, 1-46.

Forbes, K., Rigobon, R., 2002. No contagion, only interdependence: Measuring stock market co-movements. *Journal of Finance*, 57, 2223-2261.

Gomez-Puig, M., 2006. Size matters for liquidity: Evidence from EMU sovereign yield spreads. *Economics Letters*, 90, 156-162.

Holmström, B., Tirole, J., 2011. Inside and outside liquidity, first ed., MIT Press, Cambridge.

Ivashina, V., Scharfstein, D., 2010. Bank lending during the financial crisis of 2008. *Journal of Financial Economics*, 97, 319-338.

Jankowitsch, R., Mösenbacher, H., Pichler, S., 2006. Measuring the liquidity impact on EMU government bond prices. *European Journal of Finance*, 12, 153-169.

Kaminsky, G.L., Reinhart, C.M., Vegh, C.A., 2003. The unholy trinity of financial contagion. *Journal of Economic Perspectives*, 17, 51-74.

King, M.A., Wadhwani, S., 1990. Transmission of volatility between stock markets. *Review of Financial Studies*, 3, 5-33.

Kiyotaki, N., Moore, J., 1997. Credit cycles. *Journal of Political Economy*, 105, 211-248.

Krugman, P., 2008. The return of depression economics and the crisis of 2008, first ed., W.W. Norton & Company, New York.

Loretan, M., English, W.B., 2000. Evaluating 'correlation breakdowns' during periods of market volatility, in: International financial markets and the implications for monetary and financial stability. BIS, Basel, 214-231.

Manganelli, S., Wolswijk, G., 2009. What drives spreads in the euro area government bond market? *Economic Policy*, 24, 191-240.

Pagano, M., von Thadden, E.-L., 2004. The European bond markets under EMU. *Oxford Review of Economic Policy*, 20, 531-554.

Pericoli, M., Sbracia, M., 2003. A primer on financial contagion. *Journal of Economic Surveys*, 17, 571-608.

Podlich, N., Wedow, M., 2011. Credit contagion between financial systems. Deutsche Bundesbank Research Centre Discussion Paper Series 2: Banking and Financial Studies, 15.

Rehn, O., 2010. European Commissioner for Economic and Monetary Policy, debate on the euro area. European Parliament speech 10/217, Brussels, 04.05.2010.

Santillan, J., Bayle, M., Thygesen, C., 2000. The impact of the euro on money and bond markets. ECB Occasional Paper Series, 1.

Schuknecht, L., von Hagen, J., Wolswijk, G., 2009. Government risk premiums in the bond market: EMU and Canada. *European Journal of Political Economy*, 25, 371-384.

Tirole, J., 2010. Illiquidity and all its friends. *Journal of Economic Literature*, 49, 287-325.

White, H., 1994. Estimation, inference, and specification analysis, first ed., Cambridge University Press, Cambridge.