SOVEREIGN CREDIT RISK SPILLOVER

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Abstract

This thesis examines cross-market correlations between means and variances in sovereign credit markets and captures the presence of any contagion effect by focusing on parallel movements between markets in the wake of the recent crisis. Furthermore, it focuses on the effect of policy interventions on the dynamics of these correlations.

First, to look at the correlation between markets, we investigate the interaction between sovereign spreads and creditworthiness. Our results suggest that there are stable long-term cointegration relationships and significant short-term reactions between government CDS spreads to rating and outlook changes, with rating and outlook leading CDS spreads. After confirming the leading role of credit ratings, we further investigate the spillover effect from ratings to CDS spreads across markets and countries. We are concerned with the spillover effect of a change in the sovereign credit rating and outlook of one country on the sovereign CDS spreads of other countries. We find that rating and outlook announcements originating from different countries have a strong spillover effect across countries but not across regions, while countries' initial credit status has limited effect on such spillover. Moreover, the US market is a strong source of global spillover to all the countries. After controlling for US factors, the international spillover effects are found to be stronger during crisis periods than in tranquil periods. In addition, credit outlook changes have a greater impact on sovereign CDS spread responses than rating change announcements, suggesting that outlook changes carry more new information.

Furthermore, we are also concerned with the influences of rescue plans by the European Union (EU) and the International Monetary Fund (IMF) on the interdependence of sovereign credit risk, measured by CDS spreads, in the Eurozone. The study focuses on the interaction between two groups of nations, 'cores' (Austria, Belgium, France, Germany and the UK) and 'PIIGS' (Portugal, Ireland, Italy, Greece and Spain), before and after these bailouts. We are able to control for the rating and other external influences affecting sovereign CDS spreads. There are three principal findings. (1) Before the EU interventions, the spreads of the rescued countries – Greece, Ireland, Portugal and Spain (PIGS) – had a strong influence on rating changes in Austria, Belgium, France, Germany and the UK (core European countries). (2) After bailout, our results underline increased interdependencies between sovereign credit risk in the EU area, especially between the rescued country and the core countries. This suggests that these bailout plans not only increase the influence of the rescued country on the development of the core nations, but also amplify the sensitivity of PIIGS to changes in the cores. (3) Different countries will vary in their financial stability and their fundamentals will differ, so they will be expected to respond differently to a bailout. Indeed, distinctive interaction behaviours across countries, related to country-specific characteristics (fiscal outlook), is found for each of the financial policy interventions.

Second, to look at the correlation between variances, this study investigated correlation between 9 major EMU countries' CDS markets during the sovereign debt crisis, and hence examined the impacts of policy interventions on these markets, using the DCC-GARCH model. The main purpose was to assess the extent to which the policy interventions influenced the dynamics of correlations in sovereign CDS markets, after controlling for international influence (US VIX), and both domestic

and foreign sovereign credit rating and outlook. Our results suggest that correlations are time-varying for all the sample countries. Most of the policy interventions led to a significant increase in the pairwise correlations. Our interpretation is that the "two-way feedback" between the healthy country and the bailed-out country causes the public-to-public risk transfer. The increased debt and deficit partly result from assisting other troubled nations. Through policy interventions, any deterioration in the sovereign creditworthiness of the healthy countries could transmit back to the bailed-out countries. Moreover, the estimation result suggests that policy interventions, rather than VIX and credit rating/outlook, play the most direct and significant role in shaping the structure of dynamic correlation in the EMU markets.

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Abbreviation List

ADF	Augmented Dickey-Fuller
AIC	Akaike's information criterion
ARCH	Autoregressive conditional heteroskedasticity
ARMA	Autoregressive moving average
AT	Austria
BEKK	Baba-Engle-Kraft-Kroner
BG	Belgium
BIC	Bayesian information criterion
bp	basis point
CCC	Constant conditional correlation
CBOE	Chicago board of option exchange
CDS	Credit default swap
CEPR	Centre for economic and policy research
CRA	Credit rating agency
DCC	Dynamic conditional correlation
DE	Germany
DTCC	Depository trust and clearing corporation
ECB	European central bank
EFSF	European financial stability facility
EFSM	European financial stabilisation mechanism
EMBI	Emerging markets bond index
EMU	European monetary union
ESM	European stability mechanism
EU	European Union
FPE	Final Prediction Error
FR	France
FX	Foreign exchange
GARCH	Generalized autoregressive conditional heteroskedasticity

GC	Granger cause
GDP	Gross domestic production
GMM	Generalized method of moments
GR	Greece
HQIC	Hannan-Quinn information criterion
IC	Information Criterion
IMF	International monetary fund
IR	Ireland
IRF	Impulse response function
ISDA	International swaps and derivatives association
IT	Italy
MGARCH	Multivariate generalized autoregressive conditional heteroskedasticity
ML	Maximum likelihood
NBER	National bureau of economic research
OLS	Ordinary least squares
OMT	Outright monetary transactions
OTC	Over the counter
PIIGS	Portugal, Ireland, Italy, Greece, Spain
PT	Portugal
QE	Quantitative easing
SD	Standard deviation
SIC	Schwarz information criterion
SMP	curities market programme
SP	Spain
UK	Unite Kingdom
USD	US dollar
VAR	Vector autoregressive
VC	Varying correlation
VECM	Vector error correction model
VIX	Implied volatility of S&P 500 index options

CHAPTER 1

Introduction

The 1980s Latin American debt crisis, the 1997 Asian financial crisis, the 1998 Russian financial crisis and the recent Eurozone sovereign debt crisis demonstrate sovereign credit risk. When unable to meet their financial obligations, particularly government debt, both emerging and developed countries may default. Nevertheless, before the Eurozone sovereign debt crisis, the sovereign credit risk of developed economies was not considered a major concern.[1] Minimizing the risk of financial contagion and better management of its impact require actions by governments in both emerging markets and industrialized countries.

1.1 Motivation

The international financial crisis in 2008 was the most serious since the 1929 Great Depression. It started with the American subprime market, which was purely an American practice (although it did exist in moderated form in other countries, such as the UK). The bursting of the real estate bubble in the US in 2007 initiated an international financial crisis, which led to major losses for financial institutions. It spread to most of the international financial markets through the interdependence

[1] The focus before 2009 is on the actions of the European Central Bank (ECB) to address the global financial shock and stability of the banking system during most of 2009 (Lane, 2012). After late 2008, international investors began reassessing their global exposures and repatriated funds to home markets, causing cross-border financial flows to dry up (Milesi‐Ferretti and Tille, 2011). This process resulted in severe funding difficulties for countries with macroeconomic imbalances and those relying on external funding. For example, the government of the Republic of Ireland was forced to provide a two-year liability guarantee to its banks (Honohan, 2010, Lane, 2011).

characteristic of financial institutions. Investors could access foreign real estate markets through securitization.

In response to the ensuing crisis in the European Union, and principally to maintain employment, a stimulus package of 200 bn euro over 2 years was announced in November 2008. The larger member states contributed more: Germany 31%, France 13%, the UK 17%. Guarantees and credits were widely provided. For instance, Ireland offered a blanket guarantee to depositors, and the UK made use of equity injections, guarantees and central bank liquidity, and arranged a shotgun marriage for Lloyds TSB and HBOS, as well as for some failing building societies and Santander.

The Eurozone debt crisis was a public debt crisis. All the PIIGS (Portugal, Ireland, Italy, Greece and Spain), France and Germany exceeded the budgetary limit of 3% in 2009-2010, while the Eurozone average exceeded 6%. To fight against the crisis, the EU undertook large-scale measures by setting up a financial stability plan with 750 bn euros in the form of loans and equities, to support any member state in trouble. The IMF also supported the Europeans, with half that amount. The ECB lent its support by purchasing public and private debt in the Eurozone. European monetary union does not allow for control of members' budget policies. Creditors therefore feared some governments would not be able to pay back their public debt, or even to service the interest payments.

We observe increased sovereign credit default swap (CDS) spreads and greater volatility, which are proxies for sovereign credit risk, especially in Europe, since the beginning of the global financial crisis. Moreover, widening sovereign CDS spreads and higher variances are associated with extensive downgrades of sovereign credit ratings during recent tranquil periods. Sovereign CDS spreads and credit ratings published by credit rating agencies (CRAs) are both supposed to reveal the credit qualities of sovereign states, since they are based on similar fundamentals. The CRAs have a crucial task in providing information to investors (Afonso et al., 2012). Changes in ratings are perceived to reflect an external assessment of risk associated with economic fundamentals or political risk, which should have an impact on sovereign CDS spreads. However, extensive downgrades after crises have been held up as signs of failure by the CRAs to anticipate crises and alert investors. Furthermore, the actions of the CRAs have been said only to increase the cost of government borrowing (also reflected in sovereign CDS spreads), thereby precipitating a self-fulfilling prophecy. Hence, our interest is in the interactions between CDS spread changes and credit ratings. Furthermore, sovereign rating downgrades in one country could create an international contagion effect through both the wake-up call (Sachs et al., 1996) to neighbouring countries with similar macroeconomic environments and hedging channels (Kodres and Pritsker, 2002). Therefore, the correlation between credit ratings and CDS spreads are investigated in the context of spillover.

Fuelled by the extensive downgrades by CRAs, damaged credit and tightened liquidity resulted in central banks implementing the monetary policy known as quantitative easing, in an attempt to stabilize their domestic economies. Governments stepped in to provide unprecedented financial assistance to the failing banks, using public funds, which further worsened the fiscal deficit. These responses raised concerns about governments' fiscal conditions, and the CDS market became increasingly volatile. Spillover from bank credit spread to the sovereign CDS market implied there was a private-to-public risk transfer, which partly contributed to the following Eurozone debt crisis. Indeed, these initiatives detonated the European sovereign debt crisis. When a government raises funds to save its troubled economy, as happened in the Eurozone debt crisis, its public debt and deficit are dragged in. In terms of trading links, Germany's balance of goods and services with the PIIGS countries swung from a significant surplus for Germany in 2007, of 33bn euro, to a small deficit, of 1.2bn euro in 2012. Since the Eurozone countries operate under the Trans-European Automated Real-time Gross Settlement Express Transfer System, large trade imbalances resulted in huge payment delays from the PIIGS' central banks (600bn euro for Germany). Moreover, inter-holding of government bonds, derivative trading by central banks and commodity trading could also contribute to contagion. Thereafter, a public-to-public risk transfer should be expected. This assumption is supported by the rating and outlook downgrades in 2012 and 2013 for the relatively healthy countries in Europe[2], which were also the main contributors in the bailout plans. The correlation of CDS spreads caused by public-to-public risk transfer, and the dynamic correlation between variances, have not yet been fully examined, along with the impact of policy intervention between EU countries and a possible contagion effect.

With respect to the correlations between variances, from the perspective of both academics and practitioners, reliable estimates of correlations between the variances of financial instruments are critical for many of the common tasks of financial management. The instability observed on sovereign CDS spreads of one country is in part due to volatility in another market (volatility spillover), especially surrounding policy intervention date. Asset allocation and risk management rely heavily on correlations and covariances. Construction of an optimal portfolio requires a forecast

[2] Austria was downgraded by Moody's and S&P to a negative outlook on 13/02/2012, downgraded by Fitch to AA+ with a negative outlook on 13/01/2012; Germany also experienced outlook downgrade to negative by Moody on 23/07/2012; France was downgraded by Moody to Aa1 on

of the covariance matrix of the returns. In addition, to calculate the standard deviation in portfolio returns, a covariance matrix of all the assets in the portfolio is required. For hedging also, estimations of the correlations between the variances on the assets are similarly required. If there are changes in the correlations and volatilities over time in response to external shocks (policy interventions), then the hedging strategies will be ineffective and require adjustment to account for the most recent information and changes. For a better understanding of the way such correlations and variances react to financial policy interventions, a study of the nature of the correlation between volatilities over time is also necessary.

1.2 Research Question

Existing studies measuring cross-market correlation between means and variances in the context of EU sovereign CDS markets fail to explore their direction of causality and time-varying nature. This thesis presents a study that examined the dynamics of pairwise correlations in sovereign credit markets and captured the presence of any contagion effect by focusing on parallel movements between markets in the wake of the recent crisis, using the narrow definition of contagion. Furthermore, it focuses on the effect of policy interventions on the dynamics of these correlations between means and variances. However, it should be noted that the study did not seek to determine and quantify the effects of these interventions, which is a macroeconomic study. Rather, it examines sovereign credit risk interactions, by addressing the following two topics:

1. Sovereign credit risk interdependencies and the impact of credit ratings
2. Dynamic correlation in sovereign CDS variances during the Eurozone debt crisis

First, to look at the correlation between means, we investigate the interaction between sovereign spreads and creditworthiness. After confirming that credit rating changes lead changes in sovereign CDS markets, we further investigate the spillover effect from ratings to CDS spreads across markets and countries. We are concerned with the spillover effect of a change in the sovereign credit rating and outlook of one country on the sovereign CDS spreads of other countries.

With the results from that empirical analysis of the correlations between credit rating and CDS spreads, we are able to control for the rating and other external influences affecting sovereign CDS spreads. We are next concerned with the influences of rescue plans by the EU and the IMF on the interdependence of sovereign credit risk, measured by CDS spreads, in the Eurozone. The study focuses on the interaction between two groups of nations, ‘Cores’ (Austria, Belgium, France, Germany and the UK) and ‘PIIGS’ (Portugal, Ireland, Italy, Greece and Spain), before and after these bailouts.

Second, to look at the correlation between variances, this study investigated correlations between 9 major EMU countries’ CDS markets during the sovereign debt crisis, and hence examined the impacts of policy interventions on these markets, using the DCC-GARCH model. The main purpose was to assess the extent to which the policy interventions influenced the dynamics of correlations in sovereign CDS markets, after accounting for international influence (US VIX) and both domestic and foreign sovereign credit ratings.

1.3 Contribution and Findings

Our study contributes to the literature in three ways. First, we investigate spillover between sovereign CDS spreads and credit ratings, which are both natural measures of sovereign credit risk, using cointegration analysis. We suggest that credit ratings/outlooks generally lead CDS markets in the lead-lag analysis. Furthermore, we also investigate cross-border spillover effects by focusing on events originating from different regions in different business cycles, during ‘tranquil’ and ‘crisis’ periods. We check for asymmetries in the transmission of spillover effects in terms of geography and business cycle. We highlight that changes in regional rating/outlook and US markets have a significant impact on the development of CDS spreads, especially during crisis periods. We use an extended sample of data in terms of both time span and sample nations (November 2004-June 2012 for 37 countries). We differentiate between types of rating event (ratings, outlook and watch revisions) from three rating agencies (S&P, Moody’s, Fitch).

Second, to the best of our knowledge, this is the first empirical study investigating CDS spread spillover caused by public-to-public risk transfer, along with the role of policy intervention by the EU and IMF. Specifically, after controlling for the effects of credit ratings, we examine the sovereign credit risk interdependence of the bailed-out countries and other countries using lead-lag analysis, before and after government interventions. We highlight significant changes in the interdependence after bailout, which leads to our finding of credit risk contagion.

Third, a search of the literature found no study examining dynamic correlations between variances in sovereign CDS markets in the context of the Eurozone debt crisis. This study hopes to reconcile the aforementioned two streams of literature: the econometric approaches estimating the time-varying correlation between markets and the empirical analysis of the impact of policy intervention. The main findings show that the correlations between variances are dynamic and time-varying for all the sample countries. Most of the policy interventions led to a significant increase in the pairwise correlations. The temporary reaction, with a reversion to the normal range, is suggested to be an intervention-caused contagion effect. Comparing across countries, correlations with Austria and Germany are less volatile and show weaker reactions to these interventions. One of the interpretations is that the “two-way feedback” between the healthy country and the bailed-out country, as proposed by Acharya et al. (2011), causes public-to-public risk transfer. The increased debt and deficit partly result from assisting other troubled nations. Through policy interventions, any deterioration in the sovereign creditworthiness of the healthy countries could transmit back to the bailed-out countries. To assess the impact of policy intervention, our empirical analysis controlled for the external regressors, including VIX and credit rating and outlook. The estimation result suggests that credit rating/outlook and VIX do not have much impact on the dynamic conditional correlation between the variances of EMU countries, while announcements of policy interventions have a significant and consistent impact on pairwise cross-market correlations. This finding suggests that policy interventions play the most direct and significant role in shaping the structure of dynamic correlation in the EMU markets.

In terms of dataset, we cover 10 major sovereign CDS reference entities in the correlation analysis and 9 nations in the analysis, including the top four contracts: the Federal Republic of Germany, the French Republic, the Republic of Italy and the Kingdom of Spain. This allows us to examine all the major policy interventions during the crisis, including: Greece’s first and second bailout, the Ireland bailout, the Portugal bailout and the Spain bailout. Also, the comprehensive time period covers the period beginning 28 April 2009, shortly after the bank bailout programme was activated but before Greece announced its 12.5% deficit, and ending at 17 February 2013. Comparison can then be made pre- and post-intervention for each bailout.

1.4 Implications

The pairwise correlations between means and variances in Eurozone sovereign CDS markets were significantly higher during the Eurozone sovereign debt crisis. This has two significant implications from the international investor's perspective. First, the high level of correlation will diminish the effect of market portfolio diversification, and a portfolio of credit products from Eurozone countries will be subject to similar credit risk. Second, the greater volatility of this correlation suggests that the reliability of the correlation is weaker, creating doubts over any portfolio strategies that are based on estimated correlation and covariance coefficients. For these reasons, this thesis looks into the time-varying correlation coefficients and tries to capture the contagion effect of the policy interventions. It reports a comprehensive picture of international contagion, across national borders and asset classes, during the crisis period.

International investors are worried about the rising links in asset prices across national boundaries and asset classes. If cross-country and cross-market correlations change during a crisis period, the existing portfolio diversification could fail to ensure safety. If diversification strategies for portfolio management are unable to diversify risk, the portfolio will be left exposed to international shock. Failing to account for the impact of policy intervention on the correlation would result in an over-diversified and sub-optimal portfolio. Our results confirm such worries about international integration. Nevertheless, our study also provides an incentive, in that the contagion is regional rather than global. An investor seeking to optimize a CDS portfolio or portfolio containing credit risk of the EU nations can make more accurate estimates by taking into account the dynamic correlation. In a period of crisis, further portfolio diversification across international markets could help limit potential credit risk spillover. On the other hand, speculators could see a profit margin in the co-movement if they understand the direction and channels of information transmission. For arbitragers, the difference and lead-lag relation between credit derivate markets can be made more precise by taking into account the findings reported here.

For policy makers, at the country level, of the two factors affecting contagion, the more crucial is economic and political stability. It reflects the fact that co-movements are unavoidable without reform at country level. To reduce financial contagion, it is necessary to reduce the fiscal and current account deficit, enhance the quality of the financial sector, and to improve the exchange rate. Without resolving the financial stress, either by improving fundamentals or through the receipt of a rescue fund, it is not possible to stabilize the sovereign credit market.

At the EU policy level, the approval of bailout policies and the like should (amongst other considerations) be related to the identification of contagion effects. Interventions in one particular market give a strong signal for investors in similar countries. Therefore, information specific to one market is likely to be used in other markets, causing a spillover effect. This could explain why interventions are associated with higher correlation between EMU nations.

The euro was introduced to strengthen currency across financial markets and avoid devaluation. The stability pact forces each government to remain within a deficit limit, at 6%, and a debt limit, at 60%. However, the Eurozone was established without supranational control of tax, spending and transfer between poor and rich members. Although different countries fell into crisis for different reasons, excessive credit was a common factor identified by regulators and policy makers. The crisis resolution mechanism (the ESM) provides a lesson for the EU, and may serve as evidence that a future Eurobond will be required to solve the debt issue permanently. The ECB has constitutional and political obstacles to the use of quantitative easing (QE), unlike the Bank of England, which used QE to purchase the UK government debt. The ECB has nevertheless played a big part in avoiding an even worse crisis, by adopting series of “unconventional measures”. Setting up a permanent firewall to protect its members from future crisis should be on its task list.

1.5 Thesis structure

This thesis is structured as follows. In Chapter Two we discuss studies related to our two research topics: correlation between means and correlation between variances. The dataset used in the thesis is described in the Chapter Three. Chapter Four starts by examining the correlation between means by looking at the dynamics of credit ratings and sovereign CDS spreads during the global financial crisis; then we present the study of CDS interdependence during the EU debt crisis and examine the potential credit risk contagion. Chapter Five investigates correlation of variances in 9 major EMU countries’ CDS markets during the sovereign debt crisis, and hence examines the impacts of policy interventions on these markets, using the DCC-GARCH model. Conclusions and implications are summarized in Chapter Six.

CHAPTER 2

Literature review

In this chapter, research topics related to spillover and contagion between markets are discussed, beginning with the features of sovereign CDS contracts, as a proxy for the sovereign credit risk of the underlying issuer, and the foundation for this research. Then, given that there is significant disagreement over the definition of 'contagion', the concepts of 'contagion', 'interdependence' and 'spillover', as used by previous researchers, are reviewed. The concept of contagion as it is understood in this thesis is then presented.

After clarifying the aforementioned concepts, this chapter reviews the most relevant literature: spillover[3] of credit risk and contagion in terms of mean and variance. As noted in the Introduction, as indicators of sovereign credit risk, credit ratings and sovereign CDS share a number of similarities. Therefore, we start with the topic of the interaction between ratings and markets. Spillover effects are discussed both across financial markets (bond, stock and foreign exchange) and across countries (emerging countries and developed countries). Second, for spillover in the credit derivative market, we further divide the topic into: interactions within the sovereign CDS market, interactions between the sovereign and the financial CDS markets; and interactions between the CDS market and other markets.

[3] The chapter essentially reviews what may generally be termed "spillover" studies, some of which in fact look into the contagion issue, although they tend to use a different concept or do not differentiate the concept of contagion (this applies to much of the earlier research).

After the literature on spillover of returns has been discussed, another form of spillover, variance spillover, is reviewed in section 2.5. Furthermore, since this thesis tries to make a contribution to policy making by focusing on the European debt crisis, studies on bailout from sovereign debt crisis and the effect of policy interventions are discussed. Lastly, to better understand the results of the thesis, the macroeconomic literature regarding transmission channels for contagion is reviewed. A rational explanation can be found for the different responses across countries facing similar shocks.

2.1 Sovereign CDS

A credit default swap (CDS) is a financial derivative that serves as insurance against credit events that may happen to a reference entity, corporate or sovereign. CDS spread is a good proxy for the creditworthiness of the underlying issuer, for three main reasons. First, while a government bond is generally denominated in local currency, a sovereign CDS is denominated in a foreign currency, which helps to counter the effects of local inflation and foreign exchange risk. Second, its price cannot be manipulated by the government, since CDS is an over-the-counter contract that is settled on the global credit derivatives market. Consequently, CDS spreads represent the credit quality perceived by investors. Third, sovereign CDS spreads mainly capture credit risk, in contrast to bond prices, which include other risks, such as liquidity (Bai and Wei, 2012).

Changes in the credit risk of a sovereign borrower should be reflected in its sovereign CDS spread. New public information should be immediately reflected in the sovereign CDS prices, since relevant information on the health of its economy is transparent compared with the corporate sector. Sovereign CDS are contracts designed to protect sovereign debt investors from loss in extreme credit events, such as bankruptcy, failure to pay, restructuring, default, acceleration and repudiation. CDS contracts transfer the credit risk associated with sovereign bonds to a third party. There are two "legs" to a standard CDS contract. A CDS spread is the premium (premium leg), as a percentage of the notional amount of the contract, paid by the buyer in exchange for compensation (contingent leg) in the event of a default or other credit events. If pre-specified credit events occur, the settlement of CDS contracts generally follows physical delivery of bonds in exchange for the original face value. There are thus five necessary components to a CDS contract: the reference entity (debt issuer); the reference obligations; the contract term; the notional principal amount; and the selected list of credit events triggering payments. Most features of sovereign CDS contracts are identical to those of corporate ones.

The Standard International Swaps and Derivatives Association (ISDA) defines 6 credit events: (1) bankruptcy of the reference entity, (2) failure to pay (the reference entity fails to pay interest or principal when due), (3) debt restructuring (e.g. maturity extension, coupon reduction, postponement in coupon payment, or change in currency), (4) obligation default, (5) obligation acceleration, and (6) repudiation. Nevertheless, the standard type of sovereign CDS contract event is based on restructuring, repudiation and failure to pay. Bankruptcy of the reference entity is considered impossible for a government and is not covered.

Over-the-counter (OTC) sovereign CDSs accounted for half the CDS market in 1997. However, this had dropped to 5% by 2007. Since the Eurozone debt crisis, its share has risen rapidly again. According to the Depository Trust and Clearing Corporation

(DTCC[4])'s Trade information warehouse report, the outstanding gross notional value of live CDS contracts reached 15 trillion USD. According to the data for the last week of August 2011, among the top-20 reference entities by US dollar equivalent gross national amounts in CDS, 14 were sovereign entities, while 9 of the top 10 were sovereign entities. All the top 7 were government CDS contracts, with the highest volume for the Federal Republic of Germany, while the total sovereign segment reached 2.2 tn USD.

2.2 Definition of spillover, interdependence and contagion

Spillover is a broad concept, defined as changes in one financial market in response to changes in factors in other markets, no matter whether during a crisis or a tranquil period. It reflects co-movement of market returns. Spillover effects are transmissions due to links among markets. Moreover, spillover causes contagion, or, conversely, contagion is the consequence of extreme spillover (Allen and Gale, 2000, Alter and Beyer, 2014). That is, spillover is necessary but not sufficient for contagion.

Interdependence is a stable and elevated two-way link between markets, during tranquil and stress periods. Generally it is associated with fundamentals, and therefore is to be expected.

Contagion, as opposed to interdependence, suggests that the international propagation mechanisms are different during times of crisis. There is no agreement on the definition of contagion, and many definitions have been proposed. Referring to the Forbes and Rigobon (2002) and World Bank's classification, we can distinguish three definitions of contagion:

[4] CDS trading volume is published on the DTCC (Depository Trust and Clearance Corporation) website.

Broad definition

Contagion is identified with the general process of shock transmission across countries. It works in both tranquil and crisis periods and refers to general cross-country spillover effects. This definition has been used by, for example, Kaminsky and Reinhart (2000, 2003), Afonso et al. (2012), Alter and Schuler (2012), Alsakka and ap Gwilym (2012), Christopher et al. (2012) and De Santis (2012).

Restrictive definition

As probably the most controversial definition, contagion is the propagation of shocks between two markets in excess of what should be expected from the fundamentals and considering the co-movements triggered by the common shocks. The construction of the underlying fundamentals needs to be investigated, then, if this definition is to be adopted. Otherwise, we are not able to appraise effectively whether excess co-movements have occurred and then whether contagion is displayed. This definition was used by Favero and Giavazzi (2002) and Mink and de Haan (2013).

Very restrictive definition

Contagion should be interpreted as the change in the cross-country correlation/covariance that takes place during a period of turmoil. This definition is more neutral because it leaves out the problem of identifying the transmission mechanism and the fundamentals (and there is no agreement on the proper set of fundamentals). More importantly, this thesis is not the place in which to define "true" fundamentals or "pure" contagion. This definition was used in the following studies: Sander and Kleimeier (2003), Billio and Pelizzon (2003), Gande and Parsley (2005), Caceres et al. (2010), Arezki et al. (2011), Hassene and Kais (2011)

Missio and Watzka (2011), Kalbaska and Gatkowski (2012). Caporin et al. (2013), Aizenman et al. (2013), Beirne and Fratzscher (2013), Alter and Beyer (2014) and Alter and Beyer (2014).

Many papers have focused on the question of contagion, and their approaches vary with regard to the definition of contagion. The third, narrow definition implies that contagious effects are to be differentiated from 'normal' transmissions of shocks across countries, also known as interdependencies. Following this widely used definition, the task of empirical contagion studies is to investigate whether or not interdependence and causality across countries are changed in certain crisis periods.

Four major categories of tests have been utilized for evidence of contagion and information transmission: correlation of asset prices, GARCH frameworks (volatility spillover), cointegration, and probit models. Our first empirical chapter applies the approach analysing correlations between markets (stock returns, interest rate, exchange rate, market indices). According to this approach, a significant increase in correlations may be considered proof of contagion. The second empirical chapter looks at volatility spillover using the GARCH framework, by focusing on changes in correlations/covariances.

A limitation of the existing literature is that many papers assume that transmission from one market to another is a one-way process. They are therefore unable to account for the direction of causality. However, price adjustment could happen in one of the two markets concerned, and lead to changes in the other. The concern of this thesis is not the factors affecting such interaction, but revealing the direction of price information transfer (the direction of causality). Furthermore, models using returns, a first differenced variable, lose information on a possible linear combination between level variables. The use of the cointegration technique can overcome the problem of non-stationary relations and support the investigation of two-way relations, in both first difference and level.

In one of the most relevant contagion studies to have used the cointegration approach, Sander and Kleimeier (2003) extended the conventional measures of contagion by investigating changes in the existence and direction of causality on sovereign bond spreads in four crises. They found support for regional contagion for the Asian crisis, and global contagion for the Russian crisis. Hassene and Kais (2011), using the restrictive definition of contagion, tested contagion through the foreign stock exchange markets of developed countries during 2006-2009. They also chose cointegration and the VAR approach to examine correlation and causality between these countries. Although Alter and Schuler (2012) use the broad definition of contagion, their research question and methodology were related to the present thesis. They investigated the interaction between government and bank spreads using causality and cointegration analysis, for four of the five PIIGS (not Greece), Germany, France and the Netherlands. They found that, before bank bailouts, contagion moved from banks to sovereigns. After bailouts, sovereign CDS spreads were more strongly affected in the short run by financial sector shock, but the impact became insignificant in the long term.

2.3 Spillover from sovereign credit ratings

Foreign-currency sovereign credit ratings assess the ability and willingness of a government to meet its debt obligations. Changes in rating are perceived to reflect an external assessment of risk associated with economic fundamentals or political risk, which should have impact on sovereign CDS spreads. The global financial crisis attracted public attention to the role of rating agencies. Sovereign credit risk was evaluated as the most urgent risk in the global economy according to the IMF (2010). The crisis shook confidence in the strength of public and private sectors in the healthiest nations, including France, Germany and the UK. When Moody's downgraded Greece's long-term foreign currency debt from B1 to Caa1 with negative outlook on 1 June 2011, the bond prices for Ireland, Spain and Portugal were pressed down.

As one of the important measures of a country's credit risk, the sovereign credit rating directly impacts the borrowing cost of a government. International investment inflows increase as the creditworthiness of countries improve, while foreign capital flees from countries whose credit quality worsens[5]. The influence of credit rating is stronger for emerging economies with lower financial transparency. Alsakka and ap Gwilym (2009) suggest that credit ratings provide opportunities for the private sector and government to access global capital and foreign direct investment.

However, the extensive downgrades after crises are considered as signs of the failure of the ratings agencies to anticipate crises and alert investors. Furthermore, during the recent Greece debt crisis, the downgrading of that country's debt rating was criticized not only for increasing the cost of government funding but also for helping precipitate Greece's default in a self-fulfilling prophecy.

[5] Kim and Wu (2011) support this by finding a positive relation between credit quality and international bank flow from developed to emerging markets.

Table 1 Literature on rating impacts

<table>
<tr><th>Strand</th><th>Researcher</th><th>Finding</th></tr>
<tr><td rowspan="9">Impact across markets: rating on local stock, bond, FX and volatility</td><td>Hull et al. (2004)
Norden and Weber (2004)</td><td>Stock, bond and CDS markets react and help to anticipate rating changes</td></tr>
<tr><td>Afonso et al. (2012)</td><td>Bond reacts to rating and outlook changes, but not anticipate</td></tr>
<tr><td>Alsakka and ap Gwilym (2012)</td><td>Foreign exchange market reaction to rating</td></tr>
<tr><td>Reisen and Von Maltzan (1999)
Sy (2004)
Alsakka and ap Gwilym (2010)</td><td>Negative events are more informative</td></tr>
<tr><td>Ismailescu and Kazemi (2010)</td><td>Positive rating events have more impact on CDS spread</td></tr>
<tr><td>Kaminsky and Schmukler (2002)</td><td>Outlook and watch announcements contain more information than rating</td></tr>
<tr><td>Goldstein et al. (2000), Sy (2004)</td><td>Rating agencies are still criticized for failing to anticipate financial crisis</td></tr>
<tr><td>Krässl (2005)
Ferreira and Gama (2007)
Heinke (2006)
Jones et al. (1998)</td><td>Sovereign credit rating have significant impact on market volatility</td></tr>
<tr style="display:none"><td></td><td></td></tr>
<tr><td rowspan="6">Impact across countries</td><td>Fender et al. (2012)</td><td>CDS spreads of emerging nations are strongly affected by international spillover effects</td></tr>
<tr><td>Kaminsky and Reinhart (2000, 2003)</td><td>Summarize three potential transmission channels explaining the rating news spillover</td></tr>
<tr><td>Gande and Parsley (2005)</td><td>Rating spillover on sovereign bond markets of other countries</td></tr>
<tr><td>Ferreira and Gama (2007)
Li et al.(2008)</td><td>Negative rating spillover into other neighbouring countries’ stock and bond markets</td></tr>
<tr><td>Arezki et al. (2011)
Afonso et al. (2012)</td><td>Contagion effects from sovereign rating news to the European financial market</td></tr>
<tr><td>Alsakka and ap Gwilym (2012)
Christopher et al. (2012)</td><td>Regional spillover effect</td></tr>
</table>

This table summarizes the literature on the impact of sovereign credit ratings; the studies listed are reviewed in the following sections.

2.3.1 Rating impact across financial markets

There are several studies in the literature on the impact of sovereign credit ratings on domestic markets for bonds, stocks and foreign exchange (Cantor and Packer, 1996, Brooks et al., 2004, Hull et al., 2004, Norden and Weber, 2004, Hooper et al., 2008, Ismailescu and Kazemi, 2010, Alsakka and ap Gwilym, 2012). These find significant relationships between credit rating downgrades, stock return, bond and CDS spreads.

Hull et al. (2004) and Norden and Weber (2004) analyse the links between rating announcements and stocks, bonds and CDS spreads, and suggest that stock/bond and CDS markets not only respond to rating events but also anticipate rating changes. However, Afonso et al. (2012), using event study and panel analysis of daily data for EU countries from 1995 to 2010, find that bond yield spreads respond to rating and outlook. Their results suggest a bi-directional causality between bond ratings and spreads but reject anticipation of announcements.

Alsakka and ap Gwilym (2012) analyse the reaction of the foreign exchange spot market to credit signals from three agencies, Fitch, Moody's and S&P, separately, using data from 1994-2010. They find credit signals could affect both own-country exchange rate and other countries' exchange rates (spillover across countries). In addition, they suggest that credit outlook and watch notation changes have more impact than rating changes.

Reisen and Von Maltzan (1999) find a two-way causality between sovereign credit ratings and government bond yield for 29 emerging markets. If a country were listed as under review for downgrade, its bond yield would be strongly affected. Sy (2004) suggests that S&P and Moody's rating changes and negative outlook and watch could help to predict debt events. Contrarily, Ismailescu and Kazemi (2010) find that positive rating events have more explanatory power on CDS markets than negative events after examining the impact of sovereign rating announcements on CDS spreads for emerging countries during 2001–2008.

Comparing the impact of positive and negative announcements, researchers (Brooks et al., 2004, Hooper et al., 2008, Hill and Faff, 2010) have found that negative events are more informative than positive changes. Alsakka and ap Gwilym (2010) explain this as credit rating agencies' reluctance to issue downgrades. Governments are more willing to release positive news to the market early and there is less incentive to leak negative news until exposure by credit rating agencies, which leads to negative signals being more informative and influential.

Investigations of the reactions of stock and bond market in emerging markets to different types of credit rating announcements from Moody's, S&P and Fitch have found that the influence of outlook and watch announcements are stronger than rating changes. This could be because the information contained in rating changes has been already exposed in the previous outlook and watch status, such that the market does not react as significantly as might otherwise be expected.

Nevertheless, rating agencies are still criticized for failing to anticipate financial crisis (and instead simply adjust after the event) (Goldstein et al., 2000, Sy, 2004). One of the explanations for their poor performance is that agencies lack sufficient accurate information on the credit status of the issuers. Moreover, the mechanism of rating announcement makes the agencies prefer not to change their ratings until the situation is stable, rather than be forced to revise ratings shortly after an announcement. Furthermore, the agencies might be paid by issuers not to predict a crisis before it actually happens (which would further increase government funding costs). Therefore, credit rating represents a lagged indicator of crisis.

Moreover, market volatility is found to be strongly affected by sovereign credit rating. Kräussl (2005) investigates the impact of sovereign ratings from Moody's and S&P on long-term foreign currency debt between 1997 and 2000. He finds rating and outlook changes (especially for negative signals) do have a significant impact on the size and volatility of lending in emerging markets. Heinke (2006) suggests that credit ratings for German Eurobonds are ranked according to bond spread volatility, whereby lower-rated bonds show higher volatility. Hooper et al. (2008) investigate 42 countries from 1995 to 2003 and find that rating upgrades seem to lower corresponding stock market volatility, while downgrade increases volatility. Their findings are supported by Ferreira and Gama (2007), who analyse 29 countries over 1989-2003.

The effect of macroeconomic news on bond and stock market volatilities is studied by Jones et al. (1998). They examine the impact of US macroeconomic news on daily T-bond prices, and find no persistence in announcement-day volatility.

2.3.2 Rating impact across countries

Other studies have focused on the rating spillover effects across countries. Fender et al. (2012) find that CDS spreads of emerging nations are strongly affected by international spillover effects, more so during stress periods. Kaminsky and Reinhart (2000, 2003) summarize three potential transmission channels explaining the rating news spillover: trading, geography and commonalities among lenders. They suggest that financial centres play a crucial role in international spillover. Countries holding the debts of countries whose rating has been downgraded are exposed to higher risk, which in return levers up their own credit risk.

In addition, Gande and Parsley (2005), using a sample of 34 developed and emerging countries from 1991 to 2000, find that rating changes have a significant spillover effect on the sovereign bond spreads of other countries. Furthermore, negative rating, outlook and watch are found to spillover into other countries' stock and bond markets, especially in emerging markets, during crisis periods (Ferreira and Gama, 2007, Li et al., 2008).

More recently, Arezki et al. (2011) examine contagion effects from sovereign rating news to the European financial market during 2007-2010. Using the vector autoregressive (VAR) framework of Favero and Giavazzi (2002), they find rating downgrades have significant spillover effects across countries. Likewise, Afonso et al. (2012) find spillover effects from lower-rated EMU countries to higher-rated EMU countries. In addition, there is bi-directional causality between ratings and spreads within 1-2 weeks.

The regional spillover effect from credit rating signals is studied by Alsakka and ap Gwilym (2012) in the foreign exchange market. They find rating signals affect own-country exchange rate and produce strong regional spillover, especially in developed and integrated capital markets. Moreover, the impact of outlook and watch is stronger than rating changes, especially during periods of crisis. Moreover, Christopher et al. (2012) investigate both the permanent and the transitory effects of ratings on stock and bond market co-movements with a regional index, using ECM models for a sample of 19 emerging countries. Their results show rating spillover effects in regional stock and bond markets.

2.4 Spillover and contagion in credit derivative markets

The strand of literature most related to the present study concerns spillover in financial markets; some of these studies have further attempted to capture any contagion effect, although there is little consensus on the definition of contagion. Spillover reflects co-movement of market returns; contagion is essentially an extreme case of spillover. Interdependence is the stable co-movement (or links) between markets, during tranquil and stress periods, which is associated with fundamentals. Referring to the Forbes and Rigobon (2002) and World Bank classification, we can distinguish three definitions of contagion (discussed in section 2.2). Corresponding to the different concepts used, four major categories of tests have been utilized to examine evidence of contagion and information transmission: correlation of asset prices, GARCH frameworks (volatility spillover), cointegration, and probit models.

The government CDS spread is affected by various factors. Spillover from neighbour countries is one of the most significant influences. Research on the links between sovereign credit risks in financial crisis is rather limited but started growing once the Eurozone debt crisis occurred. The contagion effect from Greece to Belgium, Italy, Portugal and Spain has been studied by Missio and Watzka (2011) using a dynamic conditional correlation (DCC) model. Kalbaska and Gatkowski (2012) analyse the CDS spreads of PIIGS, France, Germany and the UK during the period 2005-2010 using EWMA correlation analysis. They argue that the correlations and interdependencies increased during the crisis, with Spain and Ireland having the largest impact on others, while the core countries were more likely to trigger contagion. Acharya et al. (2011a) find empirical evidence of two-way interactions between credit risk in banks and sovereign states. After examining the co-movement of government and bank CDS spreads, Ejsing and Lemke (2011) argue that government bailout leads to more sensitivity of sovereign CDS to future shocks. Dieckmann and Plank (2012) suggest a private-to-public risk transfer after government intervention. Alter and Schuler (2012) study a similar research question by focusing on difference in performance before and after government interventions. They find that, after bailout, the impact from the financial sector is stronger in the short run but insignificant over the long run. However, there has been no full-scale empirical study on changes in the interdependence of sovereign credit risk for EU countries before and after bailouts.

One of the most important incentives for providing financial support to the PIIGS countries, especially Greece, is the fear of contagion to highly exposed countries like France and Germany (Constâncio, 2012). Wolfgang Schauble, the German minister of finance in 2010, suggests that the systemic importance of Greece acts as a major bank and that bankruptcy would have incalculable consequences, since "it is not clear who holds how much of these debt denominated in euros" (Mink and de Haan, 2013). If EMU countries fail to undertake structural reforms, they could face rising risk. Investors are concerned about the deterioration of fiscal balances and fear of contagion from the periphery countries (Metiu, 2012). He finds a significant contagion effect on long-term bond yield.

Thus, various forms of spillover have been studied by previous researchers. Those most closely related to the present research are: spillover between sovereign states, spillover between sovereign states and financial sectors, and spillover across markets (especially for CDS and bonds).

Table 2 Literature on Spillover

Stand	Researcher	Finding
Interaction between sovereigns	Missio and Watzka (2011)	Contagion from Greece in the Euro area
	Metiu (2012)	Significant contagion effect in long-term bond yield in the Euro area
	Kalbaska and Gatkowski (2012) Caporin et al. (2013)	PIIGS countries have stronger sovereign risk contagion
	De Santis (2012)	Contagion effect from Greece rating downgrade on other PIIGS, Belgium and France
	Aizenman et al. (2013)	Contagion from rating downgrades in PIIGS to other euro countries, but after controlling for own-country credit rating changes, it is not evident.
	Hauner et al. (2010)	Creditworthiness of old EU members helps to lower the borrowing cost of new-comers
	Cochrane (2010) Caceres et al. (2010) Beirne and Fratzscher (2013)	Contagion is believed to be over-exaggerated
Interaction between sovereign and financial sector	Alter and Beyer (2014) Alter and Schuler (2012) Acharya et al. (2011a) Ejsing and Lemke (2011) Dieckmann and Plank (2012) Burnside and Eichenbaum (2001)	Co-movement between sovereign and bank CDS, support private-public risk transfer
Interaction between CDS and other markets, lead-lag analysis	Chan-Lau and Kim (2004) Norden and Weber (2004)	Mixed relation for CDS, bond and stock index in price discovery
	Blanco et al. (2005) Zhu (2006) Ammer and Cai (2011) Delatte et al. (2012)	CDS leads bond market

Three strands of literature on spillover are summarized in the table, and these are reviewed separately in the following section.

2.4.1 Interaction between sovereign states

In the European context, there are several recent papers investigating interactions across countries. Missio and Watzka (2011) examine the time-varying correlations and find contagion within the Euro area from Greece to Belgium, Italy, Portugal and Spain during the summer of 2010, using a dynamic conditional correlation (DCC) model, and document effects generated by rating announcements.

Furthermore, Kalbaska and Gatkowski (2012) compare spillover effects by analysing the CDS spreads of the PIIGS, France, Germany and the UK during the period 2005-2010 using exponentially weighted moving average correlation analysis. They find increased correlations and interdependencies after August 2007. More importantly, the Spanish and Irish CDS markets have the greatest impact on the European CDS market, contrasted with the British CDS market, which does not cause distress in the Eurozone. Their adjusted correlation analysis confirms that the PIIGS have a lower capacity to trigger contagion than core EU countries. They find Portugal the most vulnerable country in the sample and the UK the most immune to shocks. Similarly, Caporin et al. (2013) use a Bayesian quantile regression approach in order to analyse sovereign risk contagion across EU countries. They find that, although the periphery countries were heavily affected in the crisis, propagation of shocks in Europe's CDS was remarkably constant for the period 2008-2011, leading them to argue that the interdependence among different countries was stable and the risk spillover was not affected by the size of shock and that, thus far, contagion remained subdued.

Aizenman et al. (2013) investigate the impact of credit rating changes on sovereign spreads in the European Union. They find that the association between credit rating changes and spreads shifted markedly between the pre-crisis and crisis periods. European countries had quite similar CDS responses to credit rating changes during the pre-crisis period, but that large differences emerged during the crisis period between the now highly-sensitive GIIPS group and other European country groupings. They find evidence of contagion from rating downgrades in GIIPS to other euro countries, but after controlling for own-country credit rating changes, the relationship was no longer apparent. This provides further motivation for our research to control the credit rating variables.

Hauner et al. (2010) examine whether the sovereign risk of certain regions is perceived differently from other regions, by focusing on the perceived sovereign risk of new EU members. They compare new EU members with other emerging markets and find that the higher policy credibility of EU membership helps to lower the perceived sovereign risk of these newcomers.

Nevertheless, the threat of contagion is believed to be over-exaggerated, according to Cochrane (2010), who argues that contagion is “self-inflicted” and would not arise if everyone knew there would not be any bailout; the only thing that investors care about is whether other PIIGS could be bailed out too after Greece’s default. Caceres et al. (2010) examine 10-year Euro area sovereign CDS spreads from mid-2005 to early 2010 and find high volatilities in the final year of their sample. They report that, earlier in the crisis, increasing global risk aversion influenced sovereign spreads while, latterly, country-specific factors began to play a more important role. Also, Beirne and Fratzscher (2013) argue that contagion is not the main force driving CDS spreads during times of financial crisis. They find deterioration in the fundamentals, and rising sensitivity of financial markets to fundamentals is the main explanation for the rising sovereign CDS and yield spreads after the crisis. Moreover, regional spillover becomes less important, even for the euro area. Their study also finds evidence for “herding contagion”, which is a sharp and simultaneous increase in many countries, although concentrated in duration and among certain countries.

2.4.2 Interaction between sovereign sector and financial sector

Another form of spillover is from the financial sector to the sovereign sector. Financial institutions in the US and Europe have suffered huge losses from subprime mortgages, credit tightening and damaged investor confidence. In order to stabilize the domestic economy, governments and central banks of affected nations have given financial aid to financial institutions. These stabilization programmes, using public funds to rescue the private sector, raise concerns over sovereign credit risk, which has pushed up the CDS spreads since 2009. Specifically, governments extend loans to local banks or even recapitalize these banks by taking stock. These guarantees on the liabilities of the financial sector increase government debt. Shortly after their implementation of such bank rescue programmes, several EU members asked for a bailout.

Recent empirical studies have focused on the financial sector and sovereign credit risk in the sovereign debt crisis. The study most closely related to the present one, Alter and Beyer (2014), examines spillover between sovereigns and banks in the Euro area, between October 2009 and July 2012, using a vector autoregressive model of daily CDS spread changes. They find growing interdependencies between sovereigns and bonds, while mixed impacts on spillover are found for different policy interventions. They find that a shock in Spanish sovereign CDS has a greater impact on both euro area sovereigns and banks during the first half of 2012, compared with 2011, and the systemic contributions of Greece, Portugal and Ireland decrease notably after the implementation of IMF/EU programmes. Furthermore, Alter and Schuler (2012) investigate the interaction of sovereign and bank spreads, using CDS data, during the period June 2007 to May 2010 for four of the five PIIGS (excepting Greece), Germany, France and the Netherlands. They show that, before bank bailouts, contagion as shown by CDS spreads moves from banks to sovereign states. Following bailouts, sovereign CDS spreads are more strongly affected in the short run by financial sector shock but the impact becomes insignificant in the long term. Government CDS then become an important determinant of banks' CDSs. They find the spillover of credit risk is consistent across countries and rescue plans after intervention.

In now well-known research on private-public risk transfer, Acharya et al. (2011a) use Eurozone CDS data for 2007-10 to demonstrate feedback between credit risk in banks and sovereign states. Announcements of bailouts were associated with an immediate and unprecedented widening of sovereign CDS spreads and narrowing of bank CDS spreads. Following the bailouts, significant co-movement emerged between bank CDS and sovereign CDS. They note the emergence of a sizeable sovereign credit risk as a cost of bank bailouts, possibly rendering the immediate stabilization of the financial sector a pyrrhic victory and one that has received little theoretical or empirical attention.

Dieckmann and Plank (2012) examine CDS spreads in 18 advanced economies and document co-movements, finding that Euro area countries exhibit higher sensitivities to the health of the financial system and also noting private-to-public risk transfer after government intervention. Burnside and Eichenbaum (2001) argue that the cause of the 1997 Asian currency crisis was the deficits associated with bailouts for their failing domestic banks.

2.4.3 Interaction between CDS and other markets

In terms of the links of CDS markets and other markets, Chan-Lau and Kim (2004) reveal mixed relations in price discovery. They use JPMorgan EMBI+ spreads, daily CDS spreads and daily MSCI equity indices for 8 emerging markets in 2001-2003 to examine the lead-lag relationship between stock, CDS and bond markets. Their cointegration, causality test and VECM analysis for the three markets show mixed results in price discovery and causality. For example, the CDS market leads to price discovery in Russia and Colombia, while bond markets are as important as the CDS market in Brazil and Bulgaria. Similarly, Norden and Weber (2004) analyse the lead-lag relation between stock, bond and CDS markets, using a sample of 58 firms over 2000-2002, mainly in the EU and the US. They conclude from a VAR model that changes in stock prices lead the CDS and bond markets, and the cointegration relation holds for most companies. Moreover, the CDS market leads bonds in price discovery for US firms, while bonds lead CDSs for European entities.

On the other hand, Blanco et al. (2005) find a constant lead role for CDS contracts, after studying 33 US and EU investment-grade companies from 2001 to 2002. They find two key factors in explaining the deviation from CDS-bond parity. Their results show a stable cointegration relation for most of the entities, while CDS lead bonds in price discovery. This lead role of CDS results in a deviation from parity in the short run. Furthermore, Zhu (2006) assesses the equilibrium relationship between CDS and bond markets by analysing daily data from 1999-2002 for 24 corporate entities. Zhu finds stable long-term relationships between them and the short-term deviation is due to the high responsiveness of CDSs to changes in creditworthiness, while CDSs lead price discovery. In addition, Zhu suggests that credit and liquidity conditions are the main driving force affecting the CDS-bond basis. Similarly, Ammer and Cai (2011) emphasise the importance of the cheapest-to-deliver option in sovereign CDSs. They examine daily data in 9 emerging markets from 2001 to 2005 and find that CDS spreads lead bond spreads, which are represented by EMBI+ spreads.

Delatte et al. (2012) analyse the CDS premiums on underlying bond spreads for PIIGS and five core European nations, and find that CDS spreads are a good indicator of possible default during a period of crisis. Palladini and Portes (2011) also suggest the CDS market moves ahead of the bond market in price discovery, after analysing sovereign CDS and bond pricing in the Eurozone.

2.5 Spillover of volatility

Co-movement of both means and volatilities across national boundaries and asset classes are observed in financial crises (Bollerslev et al., 1988). Evidence of an international volatility contagion effect is also documented by King and Wadhwani (1990). They find that the correlation between market movements in different countries and volatility are positively related, which is fundamental to establishing the limits of diversification, pricing and asset allocation. In addition, Forbes and Rigobon (2002) investigate cross-market correlation coefficients and show that these estimation are biased and inaccurate with the existence of heteroscedasticity. They suggest that increased co-movements of different markets in crisis period could be caused by increased market volatility, which raises concern on the usual implicit assumption of constant correlation/covariance.

A number of studies have examined the interdependence of market volatility, using the framework of generalised autoregressive conditional heteroscedasticity (GARCH) time series models. For example, Silvennoinen and Teräsvirta (2008) reveal that shock to the volatility of the financial market in one country could influence both the conditional volatility and conditional mean in another country. Most of the these studies modelling volatility spillover assume conditional time-invariant correlations in order to simplify the estimation procedure (Juselius, 2006, WSJ, 2013).

Nevertheless, several studies (Hong, 2001, Engle, 2002, Chiang et al., 2007) examine the time-variability of correlation. Hong (2001) document increases in correlations among European countries' equity markets since the 1970s. Andersen et al. (2001) emphasize that covariance and correlation increases during periods of high volatility, which is generally during crisis period. Based on the multivariate constant correlation/covariance GARCH model of Bollerslev (1990), Chiang et al. (2007) apply a Dynamic Conditional Correlation (DCC) model and find increased correlation and persistent high covariance during the 1997 Asian crisis.

Johansen and Juselius (1994) examines the dynamic linkages among European bond markets, by modelling the price and volatility spillover from the US bond market and the aggregate Euro bond market to 12 European bond market. The EGARCH model they apply allows for a dynamic correlation structure. Their results suggest strong such volatility spillover, which is further strengthened by the introduction of the euro.

Steeley (2006) provides a theoretical link between stock and bond market volatility, which indicate a volatility spillover effect from the short-term interest rate market to the bond and stock market. In addition, past bond market volatility is found to be able to feeds back into the short-term yield volatility. These findings in the time-varying correlation structure between volatility in stock and bond markets have important implications for portfolio selection.

In the CDS markets, Corsetti et al. (2011) investigate volatility transmission among the CDS, equity, and bond markets, using MGARCH model. They failed to support their hypothesis that the volatility spillover from CDS market to bond and equity is caused by potential insider trading and private credit information. But strengthened links across asset classes were evident, and volatility in any of these three markets could easily be transmitted into other two markets.

More recently, Missio and Watzka (2011) focus on the links in bond markets during the sovereign debt crisis, using the DCC approach. They explain why the Engle (2002)'s model, among other multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) models, is suitable for estimation of the conditional correlation/covariance. Furthermore, Silvennoinen and Teräsvirta (2008) provide a comprehensive summary of the literature on MGARCH models.

Alter and Beyer (2014) analyse the pairwise relationships between securitized real estate markets, but also between securitized real estate and common stock markets, using data from the US, the UK and Austria from 1990 to 2010. They examine the volatility transmissions across markets using an asymmetric t-BEKK (Baba-Engle-Kraft-Kroner) specification of their covariance matrix. In addition, the market contagion is also tested for structural changes. They find support for volatility spillover by showing strong domestic and international spillover in the US. Also, they find evidence of market contagion between the US and the UK markets during the subprime crisis.

Furthermore, in some very relevant research, Beine (2004) applies a VEC model to look at the impact of central bank intervention on the variances and covariance dynamic of yen-dollar and euro-dollar exchange rates. He suggests that increases in the covariance are associated with concerted interventions.

2.6 Bailout and the sovereign debt crisis

There is limited research investigating the influence on euro area markets of bailout during the sovereign debt crisis. Of relevance here are the consequences of sovereign default. Bulow and Rogoff (1989a, 1989b) undertook a study on the ex-post costs of sovereign default on external debt. Broner and Ventura (2011) and Gennaioli et al. (2012) discuss the collateral damage to the market ensuing from sovereign default.

The literature mainly focuses on bank bailouts[6]. Sgherri and Zoli (2009) and Attinasi et al. (2009) focus on the effect of bank bailout announcements on sovereign credit risk. Demirguc-Kunt and Huizinga (2010) study the stock prices and CDS spreads around bank bailout announcements for international markets. They find that some large banks are too large to save rather than too big to fail.

In addition, Ejsing and Lemke (2011) examine the co-movement between sovereign and bank CDS spreads for 10 EU countries. They find that government bailout packages lower bank CDS spreads but increase government CDS spreads. The sensitivity of sovereign risk spreads to any further crisis events increased, while simultaneously the sensitivity of bank credit risk decreases and becomes more sovereign-like, reflecting government guarantees for banking sector liabilities.

[6] Theoretical literature on bank bailouts includes Penati and Protopapadakis (1988), Mailath and Mester (1994), Aghion et al. (1999), Gorton and Huang (2004), Diamond and Rajan (2002, 2005), Acharya and Yorulmazer (2008), Acharya et al. (2011b), Veronesi and Zingales (2010), Brown and Dinc (2011), Panageas (2010).

In terms of the impact of sovereign bailout on other markets, Mink and de Haan (2013) examine the impact of news about Greece and Greek bailout news on bank stock prices in 2010 using data for 48 banks included in the European stress tests. They find that news about Greece did not lead to abnormal returns, while news about a bailout did, even for banks not exposed to Greece or other highly indebted Euro countries. Moreover, the sovereign bond markets of Portugal, Ireland and Spain actively responded to all news about Greece, general news and bailout news, showing significant sensitivity to it. They suggest that the bailout acts like a general signal showing a willingness to use public funds to fight the crisis. Grammatikos and Vermeulen (2012) test the transmission of the 2008 financial crisis and the sovereign debt crisis in 15 EMU members, in terms of stock, CDS spreads and exchange rates. They divide EMU countries into 3 groups, North, South and Small, using daily data on financial and non-financial stock indexes in 2003-2010. They find that the small countries are more isolated from international events. Moreover, they find evidence of crisis transfer from the US non-financial sector to EU non-financials. Financials become more reliant on changes in difference between the Greek and German CDS spread after Lehman's collapse. In addition, the euro appreciates along with European stock market decreases, pre-crisis, while the relation reverses afterwards.

More studies focus on policy interventions during the crisis. Arellano et al. (2012) provide an appealing explanation for why the threat of sovereign debt crisis in Europe has been present for a long time, which leaves a couple of other major issues. Based on the study of Cole and Kehoe (1996, 2000) and Conesa and Kehoe (2012), they develop a theory to analyse the impact of rescue packages from 1992 to 2012. They find that, in a deep recession, governments prefer to "gamble for redemption" and bet the recession will end soon - which means selling more bonds in order to smooth government spending, rather than controlling it. The policy interventions, bailout and Securities Market Programme, aiming to lower borrowing costs, encourage Eurozone governments to gamble. They further suggest two reasons why other countries with large public debt and recent experience of recession, such as Japan, the UK and the US, are not threatened by these debt crises: central governments raise funds, and currencies fluctuate freely in response to economic conditions. Moreover, Arellano and Bai (2012) argue that the reason for the EU becoming a major lender, by creating European Financial Stability Facility (EFSF), is to be lenient with borrowers and try to avoid more default from other borrowers.

Moreover, Lane (2012) discusses the fiscal dimensions of the European sovereign debt crisis from an economic perspective. He argues that the creation of the euro: (1) grants a national government the ability to borrow in the common currency, which generates a free-rider problem (Buiter et al., 1993, Beetsma and Uhlig, 1999); and (2) means that national fiscal policies also serve as counter-cyclical policy (Wyplosz, 1997, Gali and Monacelli, 2008). He suggests three phases in the development of the debt crisis: first, the initial design of the euro area increased the fiscal risk in the pre-crisis period; second, these design flaws amplified the impact of crisis when it came; and third, the restrictions imposed by EMU and the ensuing political chaos shaped the duration and tempo of the post-crisis recovery period.

2.7 Transmission channels

There are various channels linking sovereign CDS spreads of different markets. Different authors emphasize different channels for contagion transmission. Generally, there are two main classes of channels (Trevino, 2014, Eichengreen et al., 1996, Kaminsky et al., 2003). One is a fundamentals channel, based on real financial links between markets. A crisis spreads across countries because their fundamentals are directly linked, through common lenders, financial markets, financial institutions or interactions between any and all of these (Pritsker, 2001).

The other is a social learning channel related to investor behaviour. Even where two countries have only weak or no fundamentals links but share similar characteristics (macroeconomic similarities), investors might fear an imminent crisis in one country after a crisis has happened in the other. This channel is considered to reflect some sort of collective “irrationality”, including panic, herd behaviour and risk aversion, although it could be individually rational. This channel can also be seen in terms of a liquidity and incentives problem, information asymmetries and market coordination problems, multiple equilibrium and changes in the international system resulting in changes in investor behaviour after the crisis (Dornbusch et al., 2000). Furthermore, it is related to the fear of contagion, which is a significant cause for sovereign risk contagion (Metiu, 2012). When macroeconomic fundamentals are not strong enough to defend a speculative attack, shift in expectations (loss of investor confidence) could lead to a self-fulfilling wave of cross-border portfolio rebalance.

These two channels are not mutually exclusive: it is reasonable to follow the actions of others in foreign market if they are linked through fundamentals. In a sovereign debt crisis, through the fundamentals channel, one country may defaults on its debt due to the default of another country that has already failed to honour its debt. Through the latter channel, a default is caused by the illiquidity following massive withdrawal based on speculation, after seeing others withdraw their funds in similar markets.

Moreover, the liquidity of the CDS market is significantly increased after a crisis, allowing investors to leverage their opinion on sovereign credit risk. Interdependence through balance sheets is one of the most important factors during a crisis. That is, over-spending leads to higher debt and deficit, this simultaneously causes a sovereign state's credit risk to increase and credit rating to be downgraded. This then in turn increases borrowing costs (bond yield spreads) and insurance costs (CDS spreads). Moreover, when the increased debt and deficit partly result from the rescue of failing domestic banks, there will be a private-to-public risk transfer, as happened in the 2008 financial crisis. Alternatively, when the increased debt and deficit partly result from assisting other troubled nations, as happened in the Eurozone debt crisis, a public-to-public risk transfer occurs. Here, though, there is the potential for a feedback mechanism, as any deterioration in the sovereign creditworthiness of the healthy countries could further transmit back to the bailed-out countries, as the rescue plan is a form of credit guarantee. "Two-way feedback" is used by Acharya et al. (2011) to describe this interdependence between sovereign and banks, which can also be used for interdependence between sovereign states.

As financial instruments with the same fundamentals, sovereign CDS and credit rating are expected to have a long-run and short-run causal relationship. Since they are traded in structurally different markets, though, there could be differences in the speed of response to respective market changes in the underlying credit conditions.

2.8 Determinates of pricing sovereign risk

The macroeconomic studies analysing the determinants of pricing sovereign risk is reviewed in this section to help explain the transmission channels of spillover and contagion. Here also the different behaviours are explained of different spillover effects across countries facing a common shock. These studies have different views on which is the dominant factor: the global market or the local fundamentals. These correspond to the two transmission channels for contagion discussed above: fundamentals and investor behaviour.

The pricing of sovereign credit risk can be categorized into two methodologies: regression and no-arbitrage models. The first type runs a regression of credit default spreads of a certain maturity on several macroeconomic or financial variables and examines the significance and magnitudes of those variables in explaining the spreads (Hilscher and Nosbusch, 2010, Longstaff et al., 2011). The second type uses latent factors to value CDS contracts in a risk-neutral world and explains credit default term structure movements based on a no-arbitrage argument (Duffie et al., 2003, Houweling and Vorst, 2005).

Longstaff et al. (2011) conduct the most influential study in this area. They analyse the determinants of sovereign credit risk by comparing local economic variables, global financial market variables, global risk premium and net investment flow into global funds. They find that sovereign credit risk is mainly driven by global financial market variables and global risk premium, rather than local macroeconomic fundamentals.

Ang and Longstaff (2013) show that sovereign credit risk is more related to financial markets than country-specific macro-characteristics. Pan and Singleton (2008b) find that sovereign credit risk is more related to global factors than country-specific factors, especially the US stock and high-yield markets.

In contrast, domestic macroeconomic fundamentals are argued to be more closely related to sovereign credit risk. Edwards (1984) looks into factors driving government bond yield, and finds domestic macroeconomic fundamentals (e.g. public debt, foreign reserves, inflation) are important determinants. Recent researchers, including Amato (2005), Packer and Zhu (2005), Cecchetti et al. (2010) and Aizenman et al. (2013), suggest that the pricing of CDS spreads is based on a set of macroeconomic fundamentals comprising public debt, fiscal balance, trade openness, external debt, inflation and TED spread. Von Hagen et al. (2011) find that bond yield spreads in the EU before and after the financial crisis could largely be explained by fundamentals. The market reacted to fiscal imbalances more significantly after the collapse of Lehman Brothers. Fontana and Scheicher (2010) propose that 'flight to liquidity' effects and limits to arbitrage could explain why CDS spreads exceed bond spreads.

De Santis (2012) examines sovereign spreads during the period September 2008 to August 2011 and suggests three factors to explain developments in sovereign spread: aggregate regional risk factor, country-specific credit ratings and spillover from Greece. He ascribes the key role of country-specific credit ratings to the developments in the spreads for Greece, Ireland, Portugal and Spain, and finds the rating downgrade of Greece contributed to developments in the spreads of the other four PIIGS, Belgium and France.

A study by Beirne and Fratzscher (2013) attempts to answer the question of to what extent the price of sovereign risk reflects macroeconomic fundamentals after the sovereign debt crisis. They analyse the drivers of sovereign risk for 31 emerging and developed economies in the European sovereign debt crisis. Their results suggest deterioration in countries' fundamentals and fundamentals contagion. The rising sensitivity of financial markets to fundamentals is the main explanation for the rising sovereign CDS and yields spreads after the crisis. Moreover, regional spillover becomes less important compared to fundamentals, even for the euro area. Their study also finds evidence for herding contagion (as defined above). In the tranquil period, the fundamentals are not fully reflected in sovereign risk.

In terms of determinants of sovereign credit ratings, another indicator of sovereign credit risk, Cantor and Packer (1996) find that ratings can be explained by per capita income, GDP growth, inflation, external debt, economic development, and default history. Afonso et al. (2007) assess the determinants of sovereign credit ratings from 1995-2005, under a panel framework and probit model. They find that GDP per capita, GDP growth, government debt, government effectiveness indicators, external debt, external reserves, and default history all contribute to the construction of credit ratings.

CHAPTER 3

Data

3.1 Sovereign CDS spreads

Different datasets are used to examine the two principal research questions. Chapter 4 uses both Dataset 1 and Dataset 2 to examine the correlation between markets, which could be further classified into two sub-research questions. Dataset 1 is used to study interactions between sovereign CDS and credit ratings, as well as international spillover, during the 2008 global crisis, while dataset 2 is used to analyse the spillover in Eurozone countries during the debt crisis and the contagion effect. The first study paves the way for the analysis of contagion by solving the omitted variables issue by controlling the rating variables. Furthermore, Dataset 2 is also used in Chapter 5 to examine the correlation between variances for EU countries.

3.1.1 Dataset 1

We divide 37 countries into four groups: Asia (8 countries), Latin America (8), Europe (16) and Middle East & Africa (5). The countries included in our dataset meet two criteria. They must have US dollar denominated sovereign CDS, and experience rating changes in long-term foreign currency debt by three major rating agencies (S&P, Moody’s and Fitch) between November 2004 and June 2012. The geographical distribution of our sample is summarized in Table 3.

Table 3 List of sample countries

Region	Countries	Total
Asia	China Indonesia Japan Kazakhstan Korea Malaysia Philippines Thailand	8
Latin America	Argentina Brazil Chile Colombia Mexico Panama Peru Venezuela	8
Europe	Austria Belgium Bulgaria Croatia France Greece Hungary Ireland Italy Poland Portugal Romania Russia Slovak Spain Ukraine	16
Middle East & Africa	Israel Lebanon Qatar South Africa Turkey	5
Total		37

This table show the geographic distribution of all the sovereign CDS markets in this study. These countries must have daily 5-year sovereign CDS spreads USD denominated ranging from November 2004 to June 2012, and long-term foreign currency debt rating changes announced by three major rating agencies.

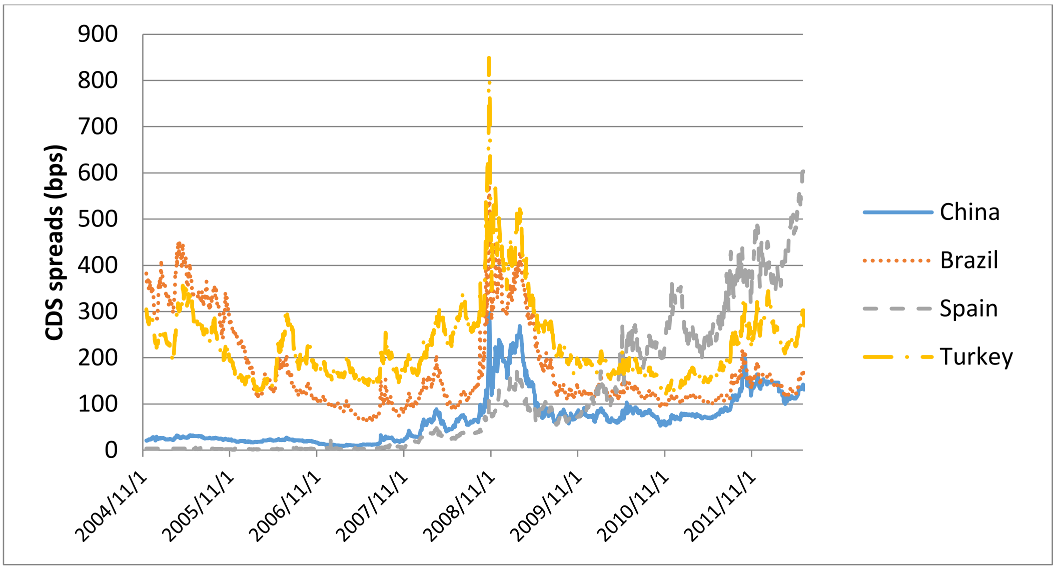
Sovereign CDS are contracts designed to protect sovereign debt investors from loss in extreme credit events, such as bankruptcy, failure to pay, restructuring, default, acceleration and repudiation. CDS spreads are the premium, as a percentage of notional amounts of contract, paid by the buyer in exchange for compensation in default (or other credit events).

We use daily CDS spreads collected from DataStream and Bloomberg [7]. Lower-frequency (e.g. monthly) data can result in higher correlations (Fender et al., 2012). These CDS spreads are for 5-year CDS contracts denominated in USD. The 5-year CDS contract is the most actively traded and liquid segment in the credit derivative market. In the following econometric analysis, we apply a logarithmic transformation of the CDS spreads. The sample period starts at November 2004 and ends at June 2012, covering the 2008 global financial crisis and the most recent Eurozone sovereign debt crisis, during which there were numerous changes in sovereign credit ratings, giving a rich dataset for analysis of the impact of these ratings. Table 4 lists descriptive statistics for daily sovereign CDS spreads, illustrating considerable differences across countries. Japan shows the smallest mean and standard deviation (SD), at 42 bp and 40.724 bp, respectively, while Ukraine is the most volatile country, with the highest mean, at 676.7 bp, and second highest SD, at 830.217 bp. Greece has the highest SD, at 1079.281 bp, and a mean at 609.2 bp. Eight countries have CDS spreads over 1000 bp: Indonesia, Kazakhstan, Argentina, Greece, Ireland, Portugal, Russia and Ukraine. The maximum CDS spread is from Ukraine, 5300.4 bp, and Greece peaks at 5047.4 bp. Figure 1 shows the time series plot of sovereign CDS spreads for four countries, China, Brazil, Spain and Turkey, from different regions. These series peak at November 2008, and start an upper trend

[7] The CDS data from Datastream and Bloomberg are provided by Credit Market Analysis (CMA).

from 2011, corresponding to the bankruptcy of Lehman Brothers and the Eurozone sovereign debt crisis.

Figure 1 Time series plot of sovereign CDS spreads for four countries in different regions



This figure plots the sovereign CDS spread for four countries from different regions in bps. They peak at November 2008, and start climbing again from 2011.

Table 4 Descriptive statistics for sovereign CDS spreads

Countries	Mean	Standard Deviation	Min	Median	Max	Observations
China	66.69	52.413	9	63.49	296.7	1974
Indonesia	230	140.931	91.4	193.5	1256.7	1974
Japan	42.94	40.724	2	23.55	157.21	1974
Kazakhstan	219.82	234.33	33.3	172.26	1646.32	1974
Korea	97.62	91.451	14	86.19	700	1974
Malaysia	81.22	65.213	12	77.09	520.2	1974
Philippines	223.3	105.825	91.9	186.3	870	1974
Thailand	99.06	67.433	24	96.31	524.2	1974
Argentina	844.4	898.804	2.5	597.2	4570.4	1974
Brazil	174	94.287	61.1	132.3	600.8	1974
Chile	68.84	57.472	12.5	63.05	315	1974
Colombia	180.4	88.444	64.7	149.2	613.3	1974
Mexico	121.71	81.764	28.17	108.36	601.21	1974
Panama	154.5	77.925	61.9	134	613.8	1974
Peru	160.1	72.864	59.9	139.3	611.2	1974
Venezuela	779.7	605.372	120	646.9	3275	1974
Austria	54.665	62.448	0.5	12.3	273	1974
Belgium	71.66	90.539	1	25.5	406.12	1974
Bulgaria	180.1	152.975	13	183.5	698.2	1974
Croatia	183.2	161.616	15	125	601.4	1974
France	46.41	60.328	0.5	13.55	249.62	1974
Greece	609.2	1079.281	4.4	57.9	5047.4	1974
Hungary	202.84	188.243	9.667	163.775	738.597	1974
Ireland	205.27	264.315	1	35.5	1191.5	1974
Italy	113.37	140.889	5.3	44.75	591.54	1974
Poland	99.257	92.155	7.667	48.75	421	1974
Portugal	232.1	366.459	1.9	41.1	1527	1974
Romania	206.46	174.029	17	200	767.7	1974
Russia	173.45	162.985	37	135.1	1116.7	1974
Slovak	69.456	78.737	5.333	24.5	328.246	1974
Spain	115.16	143.005	1.05	39.95	603.602	1974
Ukraine	676.7	830.217	1	311.9	5300.4	1974
Israel	92.82	64.315	15	91.15	285.41	1974
Lebanon	382.7	105.511	166.3	358.7	955.5	1974
Qatar	78.35	65.616	7.8	75.61	379.6	1974
South.Africa	132.9	98.877	23.8	126.2	683.3	1974
Turkey	227.4	83.844	116.9	203	849.2	1974

This table shows the descriptive statistics for daily sovereign CDS spreads for our 5-year US denominated CDS spread, in basis points (bp), from November 2004 to June 2012.

3.1.2 Dataset 2

We use daily CDS spreads collected from DataStream[8] for 10 European countries: the United Kingdom (UK)[9] and 9 in the Eurozone: Austria (AT), Belgium (BG), France (FR), Germany (DE), Greece (GR), Ireland (IR), Italy (IT), Portugal (PT), and Spain (SP). These countries are classified into two groups: Cores and PIIGS, according to their role in the financial crisis[10]. Their government debt to GDP ratio (%) and budget deficit to GDP ratio (%) are shown in Table 5, from 2007 to 2012. The sample includes major sovereign CDS reference entities, including the top four contracts: Federal Republic of Germany, French Republic, Republic of Italy and Kingdom of Spain, according to Depository Trust & Clearing Corporation (DTCC) (2013). The selection of European sovereign CDS spreads series are restricted by data availability. The data for the CDS series are for 5-year CDS contracts denominated in USD. The 5-year CDS contract is the most actively traded and liquid segment in the sovereign CDS market. We note that lower-frequency data can result in higher correlations (Fender et al., 2012). The sample period starts at April 2009

[8] The CDS data from DataStream is provided by Thomsen Reuters.

[9] Considering that it is more exposed to Irish banks, UK did voluntarily contribute to the Irish bailout, which makes it a contributor, just like the Eurozone core countries, despite its zero contribution to ESM, EFSF. Moreover, British banks have direct risk exposure to France and Germany banks, which makes UK government credit risk indirectly related to the troubled PIIGS. Moreover, over 50% of UK total trade is with the EU, accounting to 5%-6% GDP. Deep recession in the EU would be a direct hit to the UK's export. UK has part of the feature of core countries and a unique case between the core and PIIGS, which is worth investigating. Its interaction with the bailed-out countries is our particular interest, therefore it is classified into cores.

[10] The classification of PIIGS and Core follows Kalbaska and Gatkowski (2012). They represent two sets of European countries, those that needed bailout packages and those that did not. As shown in Table 5, PIIGS countries have a high debt-GDP and deficit-GDP ratios, while the core countries have relatively healthy fundamental. While Austria has the lowest Debt-GDP ratio, France, Germany and the UK own large shares of the debt of PIIGS. Belgium has the worst fundamental in the cores, but these is only small increase in Debt-GDP from 2007-2012. Spain is included in the PIIGS because of its high deficit-GDP and unemployment rate (over 20% in 2011). Using the euro as their currency, they are unable to deploy independent monetary policy to battle economic downturn.

and ends at February 2013[11], covering the sovereign debt crisis, during which the credit risk of most European countries was increased, led by Greece.

Table 5 Government Debt-GDP and Deficit-GDP, 2007-2012

	2007	2008	2009	2010	2011	2012
Panel A	*Debt-GDP (%)*					
Austria	62.8	60.7	63.8	69.2	72	72.5
Belgium	88.1	84.2	89.2	95.7	95.5	97.8
France	63.7	68.2	79.2	82.4	85.5	90.2
Germany	67.6	64.9	66.8	74.5	82.4	80.4
UK	43.4	44.5	52.3	73.9	80	86.4
Greece	106.1	105.4	112.9	129.7	148.3	170.3
Ireland	24.8	25	44.5	64.8	92.1	106.4
Italy	106.6	103.6	106.1	116.4	119.3	120.8
Portugal	63.9	68.3	71.7	83.7	94	108.3
Spain	39.6	36.1	40.2	53.9	61.5	69.3
Panel B	*Deficit-GDP (%)*					
Austria	1	1	4.1	4.5	2.4	2.5
Belgium	0.1	1.1	5.6	3.9	3.9	4
France	2.7	3.3	7.6	7.1	5.3	4.9
Germany	-0.2	0.1	3.1	4.2	0.8	-0.2
UK	2.7	4.9	10.8	10	7.9	6.5
Greece	6.8	9.9	15.6	10.8	9.6	10
Ireland	-0.1	7.4	13.9	30.8	13.3	7.5
Italy	1.6	2.7	5.4	4.3	3.7	2.9
Portugal	3.2	3.7	10.2	9.9	4.4	6.4
Spain	-1.9	4.5	11.2	9.7	9.4	10.6

This table shows the government debt to GDP ratio (%) and budget deficit to GDP ratio (%) for the 10 sample countries, from 2007 to 2012. Source: Eurostat and the European Commission

Our sample time span starts from 28 April 2009 (shortly after the bank bailout programme began but before Greece announced its 12.5% deficit) and ends at 17 February 2013. Table 6 lists descriptive statistics for daily sovereign CDS spreads in

[11] In the case of Greece, its time span ends at 21 Feb 2012, when the Greek government reformed its debt - viewed as default by the rating agencies.

level and log-transformed[12], illustrating considerable differences across countries. Germany shows the smallest mean and standard deviation (SD), at 34.318 bp and 13.033 bp in level, respectively, while Greece is the most volatile country, with the highest mean, at 1799.441 bp, and SD, at 2625.636 bp in level. The PIIGS have CDS spreads over 200 bp while the five core nations, do not. The UK, the only non-Eurozone country in the sample, has the second most stable CDS spreads, at 61.161 mean and 15.794 SD.

Figure 2 shows the sovereign CDS spreads over time for these two groups of countries. These series peak between the end of 2011 and the start of 2012, and afterwards start dropping, corresponding to the end of the sovereign debt crisis.

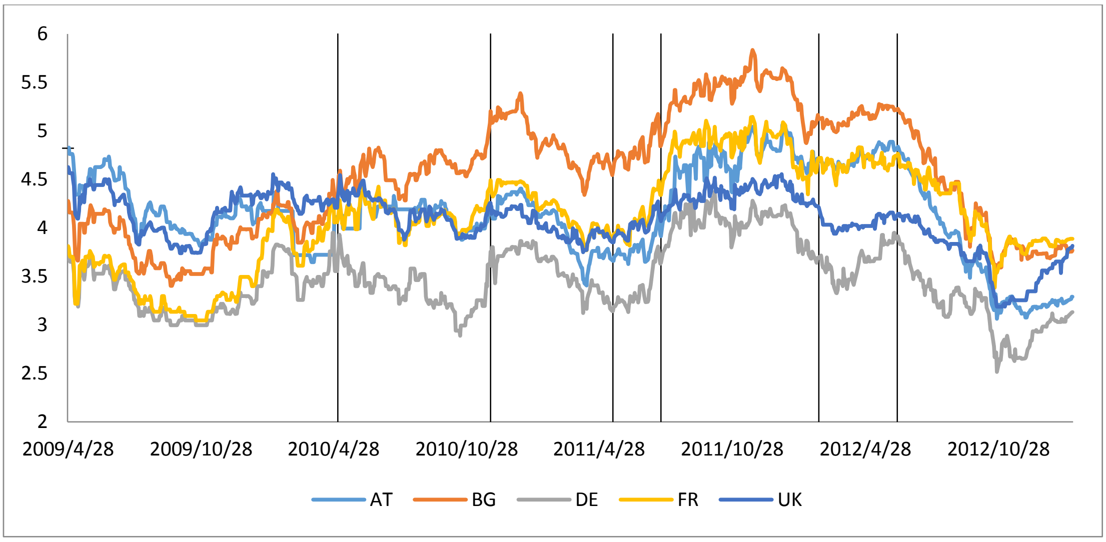
[12] Log-transform CDS spreads is to help induce homoscedasticity and normally distributed errors and ease of interpretation.

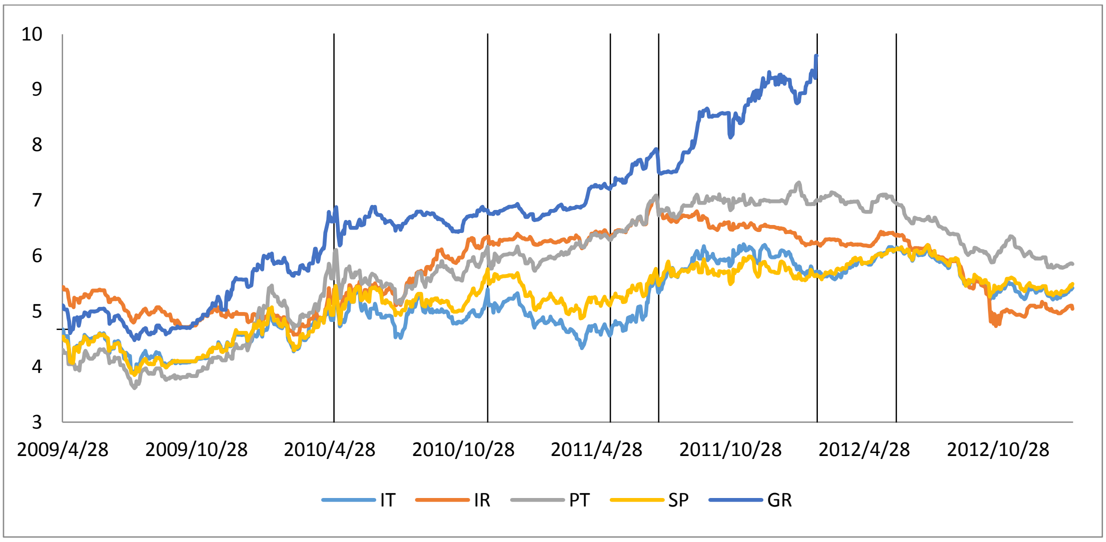
Table 6 Descriptive Statistics

	variables in levels							variables in ln								
Countries	Mean	SD	Min	Median	Max	Skew	Kurtosis	Mean	SD	Min	Median	Max	Skew	Kurtosis	Period	No. Obs
Austria	70.632	30.787	21.390	65.109	159.230	0.563	-0.480	4.157	0.461	3.063	4.176	5.070	-0.327	-0.436	28/04/2009 - 07/02/2013	988
Belgium	113.134	67.163	30.000	101.064	341.980	0.828	-0.126	4.548	0.613	3.401	4.616	5.835	-0.033	-1.115	28/04/2009 - 07/02/2013	988
France	70.151	35.099	21.000	61.590	171.560	0.757	-0.248	4.123	0.516	3.045	4.120	5.145	-0.162	-0.671	28/04/2009 - 07/02/2013	988
Germany	34.318	13.033	12.350	31.389	79.290	0.942	0.329	3.468	0.365	2.514	3.446	4.373	0.158	-0.430	28/04/2009 - 07/02/2013	988
Greece	1799.441	2625.636	88.000	817.745	14911.740	2.195	4.219	6.636	1.326	4.477	6.707	9.610	0.220	-0.736	28/04/2009 - 22/02/2012	737
Ireland	387.707	233.447	96.925	374.780	1191.158	0.472	-0.772	5.753	0.669	4.574	5.926	7.083	-0.108	-1.524	28/04/2009 - 07/02/2013	988
Italy	204.165	123.738	48.000	154.790	498.660	0.723	-0.779	5.131	0.622	3.871	5.042	6.212	0.038	-1.145	28/04/2009 - 07/02/2013	988
Portugal	506.337	385.961	37.000	397.871	1521.450	0.559	-1.010	5.811	1.039	3.611	5.986	7.327	-0.602	-0.784	28/04/2009 - 07/02/2013	988
Spain	215.493	107.113	47.000	207.105	492.070	0.323	-0.708	5.224	0.583	3.850	5.333	6.199	-0.575	-0.662	28/04/2009 - 07/02/2013	988
UK	61.161	15.794	24.210	61.255	102.000	-0.140	-0.415	4.076	0.288	3.187	4.115	4.625	-0.915	0.900	28/04/2009 - 07/02/2013	988

This table shows the descriptive statistics for daily sovereign CDS spreads for our 5-year US denominated CDS spread, in basis points (bp). Variables in levels and in logarithm are reported separately.

Figure 2 Time series plot of CDS spreads for "Core" and "PIIGS" countries





The figures present the development of sovereign CDS spreads for the "Core" countries and "PIIGS" countries, Apr 2009 – Feb 2013. The vertical lines mark the events of: Greece 1st bailout; Ireland bailout; Portugal bailout; Greece 2nd bailout; Greece 2nd bailout finalized; Spain bailout. According to the events, the time period is divided into sub-periods for analysis. "Cores": Austria (AT), Belgium (BG), France (FR), Germany (DE), and United Kingdom (UK); "PIIGS": Greece (GR), Ireland (IR), Italy (IT), Portugal (PT), and Spain (SP).

3.2 Sovereign credit ratings

There are six types of rating announcement from the agencies: downgrades, upgrades, watch/review for downgrade, watch/review for upgrade, positive outlook and negative outlook. Outlook and watch/review come under the same category of announcement by rating agencies. Outlook assesses the potential direction of credit rating over the longer term, typically six months to two years. Watch/review, as a special type of outlook, represent an agency's opinion regarding the potential direction over the shorter term.

For present purposes, outlook and watch/review are hereafter combined and simply called outlook, a variable that represents the agency's opinion on future changes. Nevertheless, a country receiving a particular outlook and having these prior ratings confirmed months later are considered as two events. Therefore, we do not mix credit rating and outlook together (Gande and Parsley, 2005) but consider them as individual variables, following Kim and Wu (2011) and Christopher et al. (2012)[13]. The sovereign credit rating and outlook for both upgrades and downgrades in sovereign CDS and bond spreads are provided by three major rating agencies: Standard and Poors (S&P), Moody's and Fitch. We employ their historical foreign currency long-term sovereign debt ratings and outlook. The reason for choosing foreign currency ratings instead of local currency ratings is that the former generally have a greater influence on asset return (Brooks et al., 2004). Table 7 shows the sovereign ratings and outlooks for long-term foreign currency debt in our sample from 15 November 2004 to 7 June 2012. Across ratings and outlooks, the numbers of upgrades and downgrades are well balanced (379 upgrades and 401 downgrades) but

[13] Credit rating, outlook and watch have different influences on the market. Hull et al. (2004) and Norden and Weber (2004) find review exhibits the most impact on the market. Christopher et al. (2012) find outlook have a greater market impact than actual rating changes.

there are more outlook events than rating events (282 ratings and 498 outlooks). Of the four regions, Europe takes the largest share of sample countries and credit events (384 events from Europe out of 780 events). Across the three rating agencies, S&P is the most active agency, announcing 287 credit events.

Table 7 Summary Description of Sovereign rating events

	Countries	Ratings		Outlooks		Total
		Upgrades	Downgrades	Upgrades	Downgrades	
S&P	37	60	53	78	96	287
Asia & Pacific	8	14	3	13	14	44
Latin America	8	21	5	19	17	62
Europe	16	17	44	36	53	150
Middle East and Africa	5	8	1	10	12	31
Moody's	36	47	30	76	96	249
Asia & Pacific	8	12	3	17	23	55
Latin America	8	16	0	19	17	52
Europe	15	9	26	29	45	109
Middle East and Africa	5	10	1	11	11	33
Fitch	36	50	42	68	84	244
Asia & Pacific	8	11	3	16	17	47
Latin America	8	18	2	14	16	50
Europe	16	16	37	31	41	125
Middle East and Africa	4	5	0	7	10	22
Total	37	157	125	222	276	**780**

This table presents the summary statistics of ratings and outlooks events for international markets grouped by region. The rating and outlook are for foreign currency denominated sovereign credit ratings and outlook events published by S&P, Moody's and Fitch. The credit status of some countries has not been adjusted by all three agencies in our sample period.

Similar to Afonso et al. (2012), Ferreira and Gama (2007), Gande and Parsley (2005) and Kaminsky and Schmukler (2002), we transform the sovereign credit ratings into a discrete variable, as shown in Table 35. The three agencies' ratings are mapped onto a 21 grade scale: AAA/Aaa=20, AA+/Aa1=19, …,, CC/C=1 and below 0. Correspondingly, the outlooks are mapped onto a scale between -1 (negative) and +1 (positive); -0.5 (watch positive) and +0.5 (watch negative). The rating and outlook variables are considered as the average across three agencies[14]:

$$Rating_{it} = \frac{1}{3}(Rating_{it}^{SP} + Rating_{it}^{M} + Rating_{it}^{F}) \tag{1}$$

$$Outlook_{it} = \frac{1}{3}(Outlook_{it}^{SP} + Outlook_{it}^{M} + Outlook_{it}^{F}) \tag{2}$$

where $Rating_{it}^{SP}$, $Rating_{it}^{M}$ and $Rating_{it}^{F}$ stand for sovereign credit ratings from S&P, Moody and Fitch, respectively. Credit outlooks from S&P, Moody and Fitch are defined in the same way.

The Rating and Outlook event distribution is shown in Figure 22. Over the sample period, there were 780 rating announcements from the three agencies, with the majority being outlook changes. There is a higher weight of rating events in Europe; smaller for Asia, Latin and Africa & Middle East. The frequency of events increases after 2008; multiple credit rating and outlook events occur on single days, reaching a peak in 2011.

In our analysis of the Eurozone debt crisis, we generate the credit rating and outlook variables using the same method. The only difference is that we expand the credit rating data from April 2009 to February 2013 for the 10 EU countries.

3.3 Bailout

The timeline of the bailouts during the Eurozone sovereign debt crisis is summarized in Table 8[15]. Each of the rescue packages is examined separately. We divide the

[14] Since the number of countries reported by these three rating agencies is slightly different, causing that there might be no rating events for some countries in our sample period, we take the average of reported agencies.

[15] Detail of bailout packages is collected from Bloomberg News.

whole sample period into sub-periods for each intervention: before and after implementation of the rescue packages[16].

For example, there are two bailout packages for Greece, €110 bn on 2 May 2010 and €130 bn on 21 July 2011. In order to examine the effects of these bailouts on the bilateral relations between Greece and other countries, we divide the sample period into three sub-periods: 28 April 2009 – 1 May 2010 (Stage 1); 2 May 2010 – 21 July 2011 (Stage 2); 22 July 2011 – 21 February 2012 (Stage 3). We next describe how the time span of each bailed-out country is defined in our analysis.

For Ireland, the bailout plan of €85 bn was announced on 28 November 2010, funded by the IMF, the European bailout fund and the EFSF. Thus, the sample is divided into two sub-periods, 28 April 2009 – 28 November 2010 and 29 November 2010 – 7 February 2013. Econometric analysis is undertaken to compare the interdependencies of credit risk of Ireland and other countries in each of the sub-periods.

As for Portugal, the EU and IMF approved a €78 bn bailout on 16 May 2011. The pre-intervention stage for this bailout plan began in April 2009 and ended in mid-May 2011, while the post-intervention stage of the bailout lasted from May 2011 to the end of the sample period. This bailout marks the most volatile period of the sovereign debt crisis.

The last bailout plan assisted Spain after the nationalization of Bankia SA in May. This €100 bn bailout package was announced on 9 June 2012, when the European

[16] This setup for investigating impact of bailout has a limitation of possible contamination from other policy interventions, like the ECB's Securities Market Program, which is also designed to stabilize the debt markets and introduced in similar date. It is further discussed in Appendix 10.

economy started to recover. In order to analyse the impact of this bailout, we divide the time span into pre- and post- bailout stages[17].

Table 8 Timeline of important events during the Eurozone sovereign debt crisis

Type	Country	Date	Event	Average ln-CDS spreads in 30 days	
				Before event	After event
Bailout	Greece	02/05/2010	EU agrees on a 110 billion euro rescue package for Greece	6.245	6.518
		21/07/2011	EU agrees the second bailout package for Greece, worth 109bn-euro	7.742	7.535
		21/02/2012	EU finance ministers finalize the detail of the second bailout package of 130bn euro, along with 50% hair cut	9.050	-
	Ireland	28/11/2010	Ireland takes a bailout from the IMF, the European Commission and EFSF (about 85 bn euros)	6.195	6.264
	Portugal	16/05/2011	The EU and the IMF approve a 78bn-euro bailout for Portugal, funded by the EFSM, EFSF and IMF.	6.342	6.456
	Spain	09/06/2012	Spain needs a 100 bn euro bailout in order to help its failing banks, after Bankia SA is partly nationalized in May	6.034	6.079

The table lists selected events in the sovereign debt crisis from 2009 to 2013. The average ln-CDS spreads in ±30 days around event dates are computed as the average changes of 30 calendar days' time windows before and after the event.

[17] Since Greece defaulted on its bonds before this rescue package was announced, the relation between Spain and Greece is not examined.

CHAPTER 4

Sovereign credit risk interdependencies and the impact of credit ratings

4.1 Introduction

The 2008-2009 global financial crisis and the European sovereign debt crisis highlight the importance of sovereign credit risk. During the crises, we observe widening sovereign credit default swap (CDS) spreads and extensive sovereign credit rating downgrades for emerging markets as well as developed economies. Sovereign CDS spread is a natural measure of a country's credit worthiness, which should reflect changes in sovereign credit risk and be of especial interest during periods of crisis. Likewise, ratings published by ratings agencies are supposed to reveal the credit qualities of sovereign states. However, extensive downgrades after crises have been held up as signs of failure by the ratings agencies to anticipate crises and to alert investors. Conversely, during the recent Greek debt crisis, the downgrading of that country's debt rating was criticized not only for increasing the cost of government funding but also for helping to precipitate Greece's default, in a self-fulfilling prophecy. Similar criticisms have been made of the rating agencies for their treatment of other countries during the Eurozone debt crisis.

Ensuring that European Union (EU) member states can endure financial shocks has been considered a major task for the success of euro since its birth (Feldstein, 1998, Wyplosz, 1997, Lane, 2006). Greece's sovereign debt crisis acted like a spark on a stack of tinder; it triggered the fear of contagion of sovereign debt crisis in other Eurozone members, especially the other PIIGS: Portugal, Ireland, Italy and Spain. In addition, although the causes of the crises varied for different nations, massive downgrades on the credit ratings for government debt further increased the cost of funding for these heavily indebted countries, and established a new set of self-fulfilling prophecies of the type mentioned above. To prevent the crisis from spreading and threatening the entire region, the EU and International Monetary Fund (IMF) stepped in and introduced various bailout packages for these troubled countries. However, credit risk is not simply eliminated by these rescue plans. Kalbaska and Gatkowski (2012) argue that bailout plans transferred the risk from PIIGS countries to other European countries, especially to the "Core" European countries, which now own large shares of the debt of the PIIGS. A full-scale empirical study is missing on the interdependence of sovereign credit risk for EU countries, and the impact of the bailouts. It is particularly important for regulators and policy makers to understand the default risk interdependence between states, the mechanism of the transmission of risk and the impacts of policy interventions, in order to avoid similar crises and to preserve the financial and monetary stability of EU.

Literature on the impact of sovereign rating announcements on CDS markets generally focuses on the short-term impact of credit rating events on stock, government bonds or foreign exchange markets around event dates, especially for domestic markets. Literature on the spillover of credit events focuses on the transmission channels or determinants of spillover effects, especially for developing markets. Studies on the European economies and their reaction to rating announcements following the start of the Eurozone sovereign debt crisis are still in progress. However, little attention has been paid to lead-lag relations between government CDS spreads and credit ratings over the long run or even short run and, furthermore, the spillover effects before and during financial crises.

We contribute to the literature by investigating bilateral linkages between sovereign CDS spreads in international markets and creditworthiness, as well as interdependence between states in this regard. We use an extended sample in terms of both time span and sample nations (November 2004-June 2012 for 37 countries). We differentiate between types of rating event (ratings, outlook and watch revisions) from three separate agencies (S&P, Moody's, Fitch). We also investigate cross-border spillover effects by focusing on events originating from different regions in different business cycles, during 'tranquil' and 'crisis' periods. We check for asymmetries in the transmission of spillover effects in terms of geography and business cycle.

Second, after examining the impact of credit ratings on sovereign CDS spreads, this study focuses on the impact of the bailout plans implemented by the EU and the IMF. Our dataset includes 10 major sovereign CDS reference entities during the period from 28 April 2009 (shortly after the bank bailout programme was activated but before Greece announced its 12.5% deficit) to 17 February 2013. This allows us to examine all the major policy interventions during the crisis: Greece's first and second bailout, the Ireland bailout, the Portugal bailout, and the Spain bailout. Moreover, we examine the impacts of financial aid on the sovereign credit risk interdependence, and explore the pattern in responses to the bailout across countries and bailouts.

We have five main findings. (1) There are stable long-run cointegration relationships and significant short-run reactions between government CDS spreads to rating and outlook changes, with rating and outlook leading CDS spreads. (2) Over the short-run, rating and outlook announcements originating from different countries have a strong spillover effect across countries but not across regions, while countries' initial credit status has limited effect on such spillover. (3) The US market is a strong source of global spillover to all the countries. (4) After controlling for US factors, the international spillover effects are found to be stronger during crisis periods than in tranquil periods. (5) Credit outlook changes have a greater impact on sovereign CDS spreads' responses than rating change announcements, suggesting that outlook changes carry more new information.

In terms of the EU sovereign debt crisis, there are three main findings. (1) Before the EU interventions, the spreads of the rescued countries – Greece, Ireland, Portugal and Spain (PIGS) – had strong influence on rate changes in Austria, Belgium, France, Germany and the UK (core European countries). (2) After bailout, our results underline increased interdependencies between sovereign credit risk in the EU area, especially between the rescued country and the core countries. This suggests that these bailout plans not only increase the influence of the rescued country on the development of the core nations, but also amplify the sensitivity of PIIGS to changes in the cores. (3) Different countries will vary in their financial stability and their fundamentals will differ, so they will be expected to respond differently to a bailout. Indeed, distinctive interaction behaviours across countries, related to country-specific characteristics (fiscal outlook), is found for each of the policy interventions.

4.2 Hypotheses

To detect the bilateral linkages (spillover) of sovereign credit markets and to capture the presence of a potential contagion effect during the Eurozone debt crisis, we are concerned with the bi-directional spillover (interdependence) of credit risk between the bailed-out countries (Greece, Ireland, Portugal and Spain) and the core countries (Austria, Belgium, France, Germany and the UK),[18] by examining the changes in the relevant interdependence throughout bailouts. Also, the study could further reveal the role of policy intervention during sovereign debt crisis. Although there might be many inter-linkages between these economies, contagion is more easily understood as a bilateral phenomenon ¸spreading from market under distress to other markets.

When spillover does occur, it can be via one or more of several channels. In terms of fundamentals, when a government raises funds to save another state in financial distress, as happened in the Eurozone debt crisis, its own public debt and deficit are contaminated. For instance, in terms of trading links, Germany's balance of goods and services with the PIIGS countries swung from a significant surplus for Germany in 2007, of 33bn euro, into a small deficit, of 1.2bn euro, in 2012. Since these Eurozone countries all operate the Trans-European Automated Real-Time Gross Settlement Express Transfer System, a large trade imbalance results in a huge payment delay from the PIIGS countries' central banks (600bn euro for Germany). Moreover, inter-holding of government bonds, derivative trading by central banks and commodity trading could also represent the contagion channels. Contagion could also arise through linkages between both fundamentals and investors' attitudes: that is, if two countries share similar characteristics (macroeconomic similarities)

[18] Belgium is considered as core nation rather than a PIIGS-type member state despite its debt/GDP ratio being around 100%, since its government deficit is relatively low and Belgium has not faced severe financing difficulty.

investors might fear a crisis in one after it has happened in the other. This seems to have been the case for spillover between the PIIGS. Fear of contagion is a significant cause for sovereign risk contagion (Metiu, 2012).

Therefore, a public-to-public risk transfer is expected through the aforementioned channels during crisis. This assumption is supported by the ratings and outlook downgrades in 2012 and 2013 for the relatively healthy countries in the EU, which were also the main contributors to the bailouts. This public-to-public risk transfer was a cause of spillover (indeed, contagion) across countries, as seen in CDS spreads. But then this spillover was intensified by the bailout. When macroeconomic fundamentals are not strong enough to defend a speculative attack, any shift in expectations (e.g. loss of investor confidence) can lead to a self-fulfilling wave of cross-border portfolio rebalancing.

Prior to any bailout, we suggest that there is significant influence of a bailed-out country's CDS spread on the core European countries, due to the rising concern over the credit risk of core countries and the links between fundamentals (inter-holding of government debt and decline in trading surplus) and investor belief (fear of contagion). Therefore, we have the following hypotheses.

H1: before bailout, changes in the assessed credit risk of bailed-out countries affect the credit risk of core European countries.

After bailout, the core nations (financing the bailout) are more exposed to the credit risk of the bailed-out countries. The fiscal situation of these core countries will then be affected by the dragged balance sheet and possibility of further action, all of which leads to a higher sensitivity to credit risk in PIIGS members. Investors' fear of contagion of further increases the trend.

H2: after bailout programs are implemented, any changes in the credit risk of bailed-out nations will have even more influence on core countries than before.

Similarly, the sensitivity of bailed-out CDS spreads to the core countries also increases after they have provided financial aid. The financial support provided by the EU and IMF, financed mainly the core countries, is supposed to have eased the financial stress of the troubled countries. The funds released with a bailout allow the receiving country (PIIGS) to lower both the cost of its future borrowing and the interest payments on its previously issued bonds, and give that country precious time to restructure its domestic economy and to lower government deficit. Nevertheless, the support of the core countries (credit guarantees for bailed-out country) makes the PIIGS more sensitive to conditions in the core nations. Since the PIIGS' domestic macroeconomic fundamentals are not good enough for those countries to defend themselves from external attack, any worsening of the fundamentals in the core countries is likely lead to panic on the part of those investing in PIIGS.

H3: after bailout, a bailed-out country's spreads are more sensitive to changes in the credit risk of core countries.

Different countries will vary in their financial stability and their fundamentals will differ, so they will be expected to behave differently in the bi-directional relation with the bailed-out countries. Comparing the different behaviour of interdependence between the bailed-out countries and others for each bailout, we try to reveal the causes for such reactions across countries in crisis period. Corresponding to the two transmission channels discussed in the literature chapter, the country-specific characteristics of any given national economic crisis is suggested as the possible main factor, including its fiscal situation (debt and deficit level) and the "information" contained in its CDS spread (investor's attitude, investors' beliefs concerning future credit risk, how informative its spreads, the possibility of a spillover). Specifically, in terms of how much a country is affected by the bailed-out countries, the vulnerability to external factors of a country depends on its fundamentals. Countries with solid fundamentals should be less affected by external shocks. On the other hand, in terms of the influence on the bailed-out countries, the influence of a country depends on its "information". Countries with more informative CDS spreads (e.g. expectation to be bailed-out) would have a larger impact on the bailed-out country. Moreover, this pattern is assumed to be consistent across the five bailouts.

H4: comparing different interactions across countries, we propose that these differences are related to the country-specific characteristic. Solid fiscal fundamentals (low debt-GDP and deficit-GDP ratios) could lead to lower sensitivity to external shocks, and more "information contained" in the CDS spread means more influence on other EU members. The "information contained" is believed to be higher if a country is expected to experience a bailout.

4.3 Methodology

There is extensive empirical evidence on testing for contagion and the transmission mechanism of shocks. Four major categories of tests have been utilized for evidence of contagion during a number of financial and currency crises: correlation of asset prices, GARCH frameworks (volatility spillover), cointegration, and probit models.

A flaw of the methodology in most existing literature is that the assumption that the transmission from one market to another is one-way. Many of the tests developed previously for contagion suffer from a simultaneity bias between correlated asset prices. Price adjustment could happen in either of the two markets, leading to changes in the other. The interest of this thesis is not the factors affecting such interaction, but revealing the direction of price information transfer.

Most of these models focus on the linkage between returns in the two markets, without considering the relationship between series in levels. One of the most important reasons is that these time series are non-stationary, which could cause spurious results. However, differencing the variables to calculate returns loses information on a possible linear combination between level variables, but the use of the cointegration technique can overcome the problem of non-stationary time series, allowing us to investigate in both first difference and level.

In order to analyse causal relationships and interdependence between pairwise markets in the long run and short run to examine spillover effects (and thereby possible contagion), we employ cointegration approach using the Vector Error Correction Model (VECM) and Vector Autoregressive Model (VAR) framework, following Sander and Kleimeier (2003), Billio and Pelizzon (2003), Hassene and Kais (2011). The VECM is to examine individual adjustment towards the long-term cointegration relationship. Although there might be many inter-linkages between these economies, contagion is more easily understood as a bilateral phenomenon ¸ spreading from a crisis market to other markets. Therefore, we trace back to the bilateral linkages, following Claeys and Vašíček (2014).

This is conducted in three steps. First, the unit root test is used to see whether or not each series is in fact stationary. Second, if a series is found to be non-stationary, cointegration tests are performed on whether a long-run equilibrium relationship exists for the pairwise markets. Third, VECM is applied to check the short-term lead-lag relationship, when the series is shown to be cointegrated, while VAR is used when it is shown not to be cointegrated. In addition, we add Granger causality and impulse response to investigate interactions between them. These techniques are able to capture changes in the dynamic relation between sovereign CDS spreads, as well as sovereign CDS and credit ratings.

4.3.1 Cointegration

We perform the standard Augmented Dickey-Fuller (ADF) unit root test on each set of rating and CDS spreads, trying to provide a parsimonious representation of the true data-generating processes. The ADF test is based on estimating the test regression:

$$y_t = \beta' D_t + \Phi y_{t-1} + \sum_{j=1}^{p} \Psi_j \Delta y_{t-j} + \varepsilon_t \tag{3}$$

where D_t is a vector of deterministic terms. The p lagged difference terms, Δy_{t-j}, are used to approximate the autoregressive moving average (ARMA) structure of the errors, and the value of p is set so that the error, ε_t, is serially uncorrelated. Under the null hypothesis, y_t is $I(1)$, which implies that $\Phi = 1$. The ADF t-statistic and normalized bias statistic are based on the least squares estimates from Eq (3).

The cointegration test is examined using both the Engle Granger ADF test and Johansen's Maximum trace and Eigenvalue test. The trend specification of these tests includes a restricted constant. When one cointegration relation is not rejected by any of the three tests, these two series are considered as cointegrated and ready to proceed to VECM analysis[19]. The critical value is decided by the Mackinnon critical value. For the VECM estimation, it is processed by the Johansen maximum

[19] This specification is in line with Ammer and Cai (2011), Alter and Schuler (2012) and Aktug (2013).

likelihood (ML) procedure, while the VAR is estimated via ordinary least squares (OLS).

The optimal lag length is chosen by Akaike's information criterion (AIC) for the ADF test with up to 12 lags, cointegration test and VECM/VAR. Other information criterion, Bayesian information criterion/ Schwarz information criterion (BIC/SIC), Final Prediction Error (FPE) and Hannan-Quinn information criterion (HQIC) are not preferred in the lag selection. In most cases, BIC/SIC would suggest one lag for the underlying VAR, which results in no cointegration relation[20]. Moreover, AIC, FPE and HQIC generally suggest the same lag length. Therefore, we use AIC for optimal lag selection. The AIC measure was chosen by Blanco et al. (2005), Zhu (2006) and Norden and Weber (2004) as their lag selection measure.

The Johansen's ML procedure VECM, with p-lags[21], is specified as below:

$$\beta_1 y_{i,t} = -\gamma_1 - \beta_2 y_{j,t} - \varepsilon_{1,t} \tag{4}$$

$$\begin{bmatrix} \Delta y_{i,t} \\ \Delta y_{j,t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{1,t-1} + \sum_{i=1}^{p-1} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta y_{i,t-i} \\ \Delta y_{j,t-i} \end{bmatrix} + u_{1,t} \tag{5}$$

$y_{i,t}$ and $y_{j,t}$ represent the series of each market. Δy_t represents the changes in y_t. $\varepsilon_{1,t-1}$ is the error correction term, corresponding to lag 1 of $\varepsilon_{1,t}$, which is the residual of the cointegration of Eq (4). The residual should be stationary when the log series are cointegrated, as tested previously. γ_1 is the restricted constant. $u_{1,t}$ are non-autoregressive *i.i.d.* residuals, with zero mean and constant variance.

[20] Kalbaska and Gatkowski (2012) suggest the one lag proposed by the SIC is not enough to investigate the relationship over long periods. Therefore, they choose AIC.

[21] p lags represent the optimal lags for the underlying VAR model; it has p-1 lags in the corresponding VECM model.

The β matrix describes the long-run relationship between two series. The α matrix, speed of adjustment, measures the speed of each market adjusting to long-run equilibrium. If α is significant and has the opposite sign to corresponding β (i.e. $\alpha_1 < 0$ and $\beta_1 > 0$), the corresponding market would adjust back to the long-run equilibrium, driven by the error correction term, ε. We can find the leading market in lead-lag analysis by comparing the magnitudes of α. (Ammer and Cai (2011), Blanco et al. (2005)) suggest using the Gonzalo and Granger (1995) measure (GG) to investigate price adjustment under the VECM framework. However, this measure requires the sign of α to be [-,+] and significant, which is defined as a real cointegration relationship, since both markets take part in the error correction; otherwise the estimation would be meaningless. Nevertheless, Enders (2004) argues that there is more than one way to correct the error. Furthermore, Alter and Schuler (2012) provide a detailed interpretation of coefficients in a VECM. When one of the α coefficients is not significant, the respective markets provide the stochastic trend in the long-run relation. When one of the α coefficients is significant but with the same sign as β, the respective variable is considered as not taking part in the error correction mechanism.

The VAR model is defined as follows:

$$\begin{bmatrix} CDS_{i,t} \\ CDS_{j,t} \end{bmatrix} = \omega + \sum_{i=1}^{p} \begin{bmatrix} \delta_{1,i} & \delta_{2,i} \\ \delta_{3,i} & \delta_{4,i} \end{bmatrix} \begin{bmatrix} CDS_{i,t-i} \\ CDS_{j,t-i} \end{bmatrix} + u_t \tag{6}$$

where ω is the intercept vector and δ represents the VAR coefficients.

4.3.2 Granger causality

In order to obtain evidence of the lead-lag relationship, we need to apply the pairwise Granger causality test. It should be noted that the result is heavily affected by the non-normality of underlying residuals.

The Granger hypothesis is set to test whether one market helps to predict the other one, or the other way round. Although it does not represent true causality, Granger causality is widely used. If A spread Granger-causes B spread, the past values of A should contain useful information to help predict B, which exceeds the information contained in the past value of B alone (Palladini and Portes, 2011).

The null hypothesis is that $y_{i,t}$ does not Granger-cause $y_{j,t}$, $c_j = 0$ for all *j*; if the statistic exceeds the 10% critical value, the null hypothesis of absence of Granger causality is rejected. We perform the following Granger causality test for series in both level and first difference in Eq (7).

$$y_{i,t} = \alpha + \sum_{m=1}^{p} b_{i,m} y_{i,t-m} + \sum_{m=1}^{p} c_j y_{j,t-m}$$

$$y_{j,t} = \alpha + \sum_{n=1}^{p} y_{j,n} y_{t-n} + \sum_{n=1}^{p} c_j y_{i,t-n} \tag{7}$$

The lag length, *p*, is chosen by Information Criteria for up to lag 12. The null hypothesis is that the series of country *i* do not Granger-cause series in countries *j*.

4.3.3 Impulse response

The Impulse Response Function (IRF) shows the response of series to a shock introduced by another variable. IRF is not looking at how one variable affects another variable, which can easily be explained by looking at the coefficients. The main task of IRF is to explain how unexpected changes that directly influence one series would affect another. In a sense, we are looking at shocks coming from the error term related to CDS spreads of one country and how such shocks change CDS spreads of others. It helps to understand which CDS market has a bigger impact on other sovereigns and how long the impact lasts.

Ordinary IRF is conducted via Cholesky decomposition, which requires specification of the causal ordering of the series. However, it can be difficult to justify such causal ordering. Generalized impulse response function (GIRF), developed by Koop et al. (1996) and Pesaran and Shin (1998), is invariant to the ordering of series. Therefore, following Alter and Schuler (2012), we choose to use GIRF to investigate the shock impact of one CDS spread on others. A positive shock – an increase in the credit risk of one country of one standard deviation – is modelled test its impact on the CDS spread in each country. Thus the shock not only affects the originating country but also countries to which it is related. We would observe the effect of the shock for 22 trading days (one calendar month). Responses are recorded in basis points.

The GIRF can be written as follows:

$$\begin{bmatrix} y_i^i(n) \\ y_i^j(n) \end{bmatrix} = \sigma_{(i,i)}^{-1/2} \Phi_n \Sigma_u \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} y_j^i(n) \\ y_j^j(n) \end{bmatrix} = \sigma_{(j,j)}^{-1/2} \Phi_n \Sigma_u \begin{bmatrix} 0 \\ 1 \end{bmatrix} \tag{8}$$

where Φ_n is the moving average coefficients measuring the impulse response at period *n*. Σ_u represents the variance-covariance matrix of residuals. $\sigma_{(j,j)}^{-1/2}$ denotes the normalization term, which is the standard deviation related to the error of shock variable. A VECM setup is adopted for the period showing the cointegration relation between CDS spreads, while a VAR setup is chosen for the period without any cointegration relation.

4.3.4 Limitations

There are several limitations to the VAR/VECM approach. First, the model has an identification problem, which is caused by there being more parameters in the structural form than in the reduced form. In the reduced form VAR, there is no contemporaneous interaction between variables. To understand the contemporaneous relations, we need to study the transmission between structural form and reduced form. If the reduced form coefficients are compatible with many different values for the structural coefficients then the model is said to be under-identified. If generally it is not possible to find any values for the structural coefficients that are compatible with the reduced form coefficients then the model is said to be over-identified. If one and only one value of each structural coefficient is compatible with the reduced form coefficients the model is said to be just identified or exactly identified.

The VAR model can satisfy OLS and ML estimation results only with relatively few variables. By imposing constraints on the parameter to limit the size of estimated parameters, various methods are proposed to solve the excessive parameter issue, like SVAR. These constraints generally come from economic theory, to demonstrate the meaningful long-run and short-run relation between economic variables and structural impulses. Over the short run, contemporaneous interactions and correlated errors complicate the identification of the nature of shocks and hence the interpretation of the impulses. Therefore, Choleski decomposition is used to identify the short-term structure (Juselius, 2006). Over the long run, we need to impose some structures on the β (cointegration space) of the model (Johansen and Juselius, 1994).

The second limitation to the VAR/VECM approach, which is related to correlation coefficients, is that if different sub-samples are to determine contagion, biased results can be produced if heteroscedasticity is not accounted for. Some researchers suggest that the increased correlation could be caused by volatility increase during crisis periods. After accounting for heteroscedasticity, there is no significant increase in correlation between asset series. This issue can therefore be solved by applying a GARCH-type approach to investigate market return volatility, as explained in the following chapter.

Third, in addition to a lagged dependent variable, an omitted variable problem arises, because there are no exogenous variables determining CDS spreads. It is unreasonable to assume that a country's CDS spreads respond only to changes in other countries' CDS spreads. This is a methodological obstacle in economic structural analysis and policy evaluation more generally. In the empirical analysis, we add exogenous variables, including ratings and outlook, as well as US factors.

4.4 Data

This chapter uses data described in Chapter 3 to examine two sub-research questions in correlation between markets. Sovereign CDS Dataset 1 and sovereign credit ratings are used to study interactions between sovereign CDS and credit ratings, as well as international spillover, during the 2008 global crisis. Sovereign CDS Dataset 2, sovereign credit ratings and bailout timeline are used to analyse the spillover in Eurozone countries during the debt crisis and capture the contagion effect. The impact of bailout is investigated by comparing the interaction before and after bailout events.

4.5 Results of spillover between credit rating and sovereign CDS spreads

Most empirical research uses event-study techniques to examine whether CDS spreads around rating event dates are abnormal. This approach, though useful, does have drawbacks. First, the time window chosen can determine the final conclusion. Second, information transmission may be bi-directional rather than one way. Moreover, running a regression with first differenced variables may lose long-run information, since the first differenced regression results are for short-run relationships. We avoid these difficulties by using the vector error correction model (VECM); running the regression with cointegrated variables at level can measure the long-run dynamic, as well as investigate the short-run revision speed, along with Granger causality, as described in Chapter 3.

Our econometric approach has two main parts. First, we start with a Granger causality test to reveal the bi-directional dynamic between sovereign CDS spreads and creditworthiness. Then cointegration and VECM tests are performed in order to investigate links between CDS spreads and credit rating and outlook, respectively, over both the long run and the short run. In the second part, we investigate spillover effects across countries by using explanatory variables under a fixed-effect panel regression framework. We focus on whether these spillovers are regional or global and whether there are the differences between times of crisis and tranquil periods.

4.5.1 Causality

The major credit ratings agencies are expected to anticipate crises and warn investors by revising their ratings. However, they are frequently criticized by observers for aggravating sovereign credit risk through unjustified rating revision (Claeys and Vašíček, 2012). Consequently, it is worth investigating the short-term causality between sovereign CDS spreads and ratings, using a bi-directional Granger causality test. The Granger hypothesis is to test whether ratings/outlooks help to predict the CDS spreads, or the converse. Although Granger causality does not imply true causality, it serves as a helpful aid to the VECM.

Table 9 shows the Granger causality test results, for both level and first difference. The lag length, p, is chosen by SIC up to lag 12. Our estimations suggest a mixed causality relationship between sovereign CDS and ratings/outlooks for different regions of the world. There is a weak form of one-way causality rather than two-way, while spread changes in the Philippines, Thailand, Brazil, Colombia, Greece, Hungary, Ukraine and South Africa are able to Granger-cause their rating changes. Ratings in Poland, Slovak, Israel and Qatar could Granger-cause their spread. Outlook in Japan, South Korea, Philippines, Colombia, Venezuela, Greece, Ireland, Poland, Slovak and Turkey is Granger-caused by the government spread. Only a few countries show a causality relation in both directions between CDS spreads and rating/outlook, and these are mainly in Europe: Bulgaria, Croatia, Hungary, Romania and Russia. Thus, our results suggest that the causality relation is rather mixed for different countries.

Table 9 Granger causality test

	cds not GC rating		rating not GC cds		cds not GC outlook		outlook not GC cds	
	level	1st difference	level	1st difference	level	1st difference	level	1st difference
Asia								
China	0.14	2.842*	4.944**	2.282	3.521*	0.18	3.768*	4.442**
Indonesia	0.386	0.038	0.357	0.74	0.317	1.772	0.409	0.296
Japan	0.955	0.163	0.489	0.281	3.388**	0.468	1.014	0.691
Kazakhstan	1.125	0.029	1.739	0.745	0.498	0.335	0.667	0.275
Korea	0.054	3.411*	1.053	3.201*	0.251	2.996*	1.028	1.454
Malaysia	0.02	0.141	0.886	2.478	0.179	0.288	0.93	1.075
Philippines	8.011***	0.052	0.231	0.739	4.238**	0	0.493	1.605
Thailand	7.062***	0.068	0.051	0.481	2.536	0.081	0.936	0.007
Latin								
Argentina	0.183	0.169	0.08	0.054	0.144	0.053	0.079	0.017
Brazil	4.867**	0.313	0.087	0.06	0.058	0.073	1.737	1.409
Chile	1.657	0.008	1.927	0.09	1.196	0.208	0.486	0.035
Colombia	3.569**	0.304	0.203	0.358	0.829	0.382	1.438	0.354
Mexico	0.258	0.02	2.106	0.625	6.221***	1.997	0.022	0.595
Panama	0.118	0.01	0.017	0.229	0.048	0.012	1.25	0.275
Peru	0.33	0.059	0.255	0.07	1.582	0.041	0.843	0.589
Venezuela	6.813***	7.19***	2.457*	1.124	2.805*	3.478**	1.458	1.032
Europe								
Austria	0.576	0.083	0.202	0.248	0.856	0.375	0.149	0.182
Belgium	1.719	0.069	0.559	0.484	1.641	0.143	0.228	0.281
Bulgaria	3.446**	0.492	2.862*	1.159	2.219	0.103	0.006	0.883
Croatia	5.99**	0	0.04	14.643***	11.537***	1.448	4.915**	2.805*
France	1.116	0.177	0.029	0.057	0.504	0.176	0.072	0.063
Greece	6.482**	0	0.083	0.007	5.569**	0.475	0.335	0.101
Hungary	11.549***	0.001	0.068	0.191	14.688***	0.175	14.332***	1.903
Ireland	0.961	0.039	0.235	0.056	4.018***	0.063	1.642	0.002
Italy	2.127	1.629	0.041	0.325	0.868	0.196	0.895	0.83

Table 9 (*continued*)

Poland	1.168	0.047	4.946**	0.205	2.369*	0.913	0.438	0.958
Portugal	1.141	0.475	0.422	0.342	2.6	0.065	1.193	1.789
Romania	7.73***	2.929*	5.029**	4.332**	0.109	0.895	4.372**	0.026
Russia	7.089***	0.041	6.974***	1.239	8.949***	0.192	5.173**	2.069
Slovak	0.646	1.918	3.323*	2.787*	3.224*	0.267	0.845	0.411
Spain	0.149	0.072	0.114	0.061	0.693	0.088	0.168	0.015
Ukraine	21.897***	17.896***	0.408	0.468	12.306***	10.924***	6.685***	7.591***
Middle East & Africa								
Israel	1.954	0.775	13.06***	0.078	0.097	0.282	0.088	0.005
Lebanon	0.134	0.244	0.761	0.714	0.408	0.069	0.253	0.218
Qatar	0.075	0.406	22.253***	19.461***	0.05	0.016	1.335	1.362
South Africa	31.417***	31.5***	0.715	0.688	0.693	0.133	0.901	0.509
Turkey	1.001	0.257	0.012	0.305	2.707*	1.297	0.217	1.252

The Granger causality test provides direction of information flows, when the lag is chosen by SIC/BIC. Its F-test results are summarized. The test equation is $y_t = \alpha + \sum_{i=1}^{5} b_i y_{t-i} + \sum_{j=1}^{5} c_j x_{t-j}$, the null hypothesis is that x does not Granger-cause y, $c_j = 0$ for all j. if the statistic exceeds the 10% critical value, the null hypothesis of absence of Granger causality is rejected. The p-values are shown below while its significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

4.5.2 Dynamic between CDS spreads and rating and outlook

Table 10 reports the results of the unit root test. For each country, the null hypothesis of a unit root is not rejected at the 5% level for both the CDS premium and the credit rating series. In order to examine the long-term and short-term dynamics between sovereign CDS spreads and credit rating/outlook, we model the CDS spreads and rating/outlook using Engle and Granger two-step OLS for estimating VECM, specified as below[22]:

CDS and Rating

$$\beta_1 CDS_t = -\gamma_1 - \beta_2 Rating_t - \varepsilon_{1,t} \tag{9}$$

$$\begin{bmatrix} \Delta CDS_t \\ \Delta Rating_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{1,t-1} + \sum_{i=1}^{p} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta CDS_{t-i} \\ \Delta Rating_{t-i} \end{bmatrix} + u_{1,t} \tag{10}$$

CDS and Outlook

$$\beta_1 CDS_t = -\gamma_1 - \beta_2 Outlook_t - \varepsilon_{1,t} \tag{11}$$

$$\begin{bmatrix} \Delta CDS_t \\ \Delta Outlook_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{2,t-1} + \sum_{i=1}^{p} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta CDS_{t-i} \\ \Delta Outlook_{t-i} \end{bmatrix} + u_{2,t} \tag{12}$$

where CDS_t are the log forms of government CDS spreads at time t. $Rating_t$ and $Outlook_t$ are the foreign currency sovereign credit ratings and outlook of the issuer at time t, defined in Eq (1)(2). ΔCDS_t, $\Delta Rating_t$ and $\Delta Outlook_t$ represent the changes of CDS_t, $Rating_t$ and $Outlook_t$ respectively. $\varepsilon_{1,t-1}$ and $\varepsilon_{2,t-1}$ are the error correction terms, corresponding to lag 1 of $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$, which are the residuals of cointegration Eq (9)(11). The residuals should be stationary when the

[22] The lag i, selected by AIC, suggest one lag for all countries.

log-CDS and rating and outlook are cointegrated, as tested previously. γ_1 and γ_2 are the restricted constants.

The β matrix describes the long-run relationship between sovereign CDS spreads and credit rating/outlook. The α matrix, speed of adjustment, measures the speed of each market adjusting to long-run equilibrium. If α is significantly negative, the corresponding market would adjust back to the long-run equilibrium, driven by the error correction term, ε. We can find the lead market in the lead-lag relation by comparing α. Blanco et al. (2005) and Ammer and Cai (2011) suggest using the Gonzalo and Granger (1995) measure (GG) to investigate the question under the VECM framework. However, this measure requires the sign of α to be [-,+] and significant; otherwise the estimation is meaningless. Nevertheless, Enders (2004) argues that there is more than one way to correct the error, and suggests three scenarios. Further, Aktug (2013) claims that there are five different cases to correct a positive error and another five cases to correct a negative error[23]. Thus, they propose a simple measure, $\alpha_2 - \alpha_1$, to check the adjustment, which should be positive to make the error correction mechanism work. CDS markets adjust to equilibrium when α_1 is negative. Correspondingly, rating and outlook adjust to the equilibrium when α_2 is positive.

Table 10 shows the results of the unit root test, suggesting that all the CDS series have a unit root, while the rating of Malaysia, Slovak and South Africa is stationary. Moreover, the outlook of Israel and Qatar also do not have a unit root, which would not proceed to the next step of analysis. Table 37 summarize the cointegration

[23] The five cases are: an increase in A (CDS) and a larger increase in B (rating/outlook); a decrease in A and a smaller decrease in B; a decrease in A and an increase in B; a decrease in A and no change in B; no change in A and an increase in B.

relation between sovereign CDS spreads and rating/outlook. Results of Augmented Dickey Fuller (ADF) and Johansen Trace and Max Eigenvalue test statistics with restricted constants are reported, along with lags. The cointegration relation of spreads and rating is accepted when any test indicates the existence of one cointegration at the 10% level, resulting in 21 countries in total: Indonesia, Japan, Philippines, Argentina, Brazil, Colombia, Mexico, Panama, Peru, Venezuela, Bulgaria, Greece, Hungary, Ireland, Romania, Russia, Spain, Ukraine, Israel, Lebanon, and Turkey. Similarly, for the cointegration between CDS and outlook, we find 16 cointegrated countries at the 10% level: China, Japan, Philippines, Argentina, Brazil, Colombia, Mexico, Panama, Peru, Croatia, Hungary, Ireland, Russia, Ukraine, Lebanon, and Turkey. Other countries would not proceed to the VECM analysis, since there is no long-run equilibrium between them. The results show that more CDS spreads are cointegrated with credit ratings than with credit outlooks.

Table 11 and Table 12 show the VECM estimation results of sovereign CDS spreads and credit rating/outlooks. Significant β shows a strong long-run equilibrium relationship between sovereign CDS spreads and rating/outlooks. The negative sign of β confirms that, as the credit quality of a country improves, its CDS spreads narrow in the long run, since CDS spread is also a benchmark measuring default risk as the credit rating. A positive sign suggests spreads shift in the same direction as the rating or outlook. In Table 11, 15 out of 21 countries have negative β, (exceptions include Argentina, Mexico, Russia and Israel), showing the majority of CDS spreads are negatively related to rating changes. All countries with negative β, in the relationship between CDS spreads and outlooks, support this. Furthermore, CDS spreads move with outlook changes more closely than with rating changes, which may be interpreted as the informational effect of rating events being diminished by earlier outlook events. Investors become less sensitive to rating changes.

The adjustment speed coefficient matrix, α, suggests market adjustment from deviation to long-run equilibrium. For the VECM estimation of CDS and rating, the Japanese spread adjusts at the rate of $\alpha_1 = -0.007$ bp, while the rating does not adjust significantly. This means that the credit rating leads CDS spreads. For comparison, Bulgaria's sovereign CDS market leads the rating at $\alpha_2 = -0.001$ bp. Using the Aktug (2013) measure, $\alpha_2 - \alpha_1$, is shown in the last column of Table 11 and Table 12. The majority of $\alpha_2 - \alpha_1$ is positive (16 out of 21 for CDS & rating, 11 out of 16 for CDS & outlook), meaning the error correction mechanism works properly. The CDS spreads decrease to correct the error in 16 countries. Thus, ratings generally lead the sovereign CDS spreads in price adjustment. Likewise, CDS spreads decrease in 11 countries while none of the credit outlooks increase, which confirms that outlook leads CDS spread in the lead-lag relation. It may be inferred that ratings and outlooks contain important information about the sovereign creditworthiness of a country and the informational effects have strong impact on the sovereign CDS markets. Particularly when most of the cointegrated countries are emerging markets, ratings agencies plays a more essential role in revealing their creditworthiness.

One possible explanation for this result is that getting information on the emerging markets is difficult for international investors, due to a lack of transparency. However, ratings agencies are able to access crucial information through various channels which play an important role in information discovery. Alsakka and ap

Gwilym (2009) suggest that credit ratings provide more opportunities for the private sector and government to access global capital and foreign direct investment.

Table 10 Unit root test

Country	CDS	Rating	Outlook
Asia			
China	-1.17	-1.39	-2.34
Indonesia	-2.3	-0.63	-2.1
Japan	-2.04	1.15	-1.03
Kazakhstan	-1.25	-0.88	-1.42
Korea	-1.41	-1.05	-1.64
Malaysia	-1.54	**-9.87**	-1.9
Philippines	-2.67	-0.49	-1.56
Thailand	-1.76	-1.42	-1.87
Latin America			
Argentina	-2.46	-1.81	-2.62
Brazil	-2.68	-0.9	-2.62
Chile	-1.18	-1.22	-3.09
Colombia	-2.83	0.25	-1.91
Mexico	-1.88	-3.04	-2
Panama	-2.62	0.57	-2.3
Peru	-3.01	-0.74	-2.17
Venezuela	-1.04	-3.33	-2.54
Europe			
Austria	-1.3	-0.23	1.18
Belgium	-0.94	1.07	1.05
Bulgaria	-0.83	-3.06	-1.46
Croatia	-0.48	-1.74	-1.45
France	-1.08	-0.23	1.76
Greece	0.35	2.09	-1.17
Hungary	-0.94	0.42	-1.86
Ireland	-2.18	1.82	-0.71
Italy	-0.37	2.18	-0.13
Poland	-0.89	-1.41	-1.98
Portugal	-0.58	2.63	-0.77
Romania	-0.6	-2.19	-1.49
Russia	-1.45	-1.25	-1.72
Slovak	-0.74	**-3.69**	-2.12
Spain	-1.05	5.77	-0.61
Ukraine	-3.22	-0.67	-1.78
MidEast & Latin			
Israel	-1.05	-0.4	**-5.5**
Lebanon	-3.22	0.02	-2.43
Qatar	-0.87	-2.23	**-4.36**
South Africa	-1.4	**-3.66**	-2.84
Turkey	-2.86	-0.84	-1.68

The ADF test indicates the presence of a unit root at the 1% level for all the CDS, rating and outlook series. The table repots the t-Statistics for the null hypothesis of a unit root. For ADF test, critical values are taken from Mackinnon Critical value, the null hypothesis of a unit root is rejected in 1% are emphasized in bold.

Table 11 VECM estimation for CDS & Rating

Country	α_1	α_2	β_1	β_2	const	α_2 - α_1
Asia						
China	-	-		-	-	-
Indonesia	-0.004**	-0.001	1	-0.069***	5.895***	0.003
Japan	-0.007**	-0.001	1	-1.876***	37.203***	0.006
Kazakhstan	-	-		-	-	-
Korea	-	-		-	-	-
Malaysia						
Philippines	-0.005**	-0.004***	1	-0.074***	5.93***	0.001
Thailand	-	-		-	-	-
Latin						
Argentina	-0.016***	0	1	0.379***	4.761***	0.016
Brazil	-0.006**	-0.003**	1	-0.132***	6.358***	0.003
Chile	-	-		-	-	-
Colombia	-0.006***	-0.003**	1	-0.129***	6.364***	0.003
Mexico	-0.005**	-0.001	1	0.64***	-3.349***	0.004
Panama	-0.006**	0	1	-0.101***	5.973***	0.006
Peru	-0.008***	-0.001	1	-0.007	5.07***	0.007
Venezuela	-0.001	-0.002	1	-0.171***	7.528***	-0.001
Europe						
Austria	-	-		-	-	-
Belgium	-	-		-	-	-
Bulgaria	-0.001	-0.001**	1	-0.032	5.044***	0
Croatia	-	-		-	-	-
France	-	-		-	-	-
Greece	0	-0.005**	1	-0.395***	9.497***	-0.005
Hungary	-0.001	-0.003***	1	-0.818***	15.208***	-0.002
Ireland	-0.012***	-0.003***	1	-0.555***	13.835***	0.009
Italy	-	-		-	-	-
Poland	-	-		-	-	-
Portugal	-	-		-	-	-
Romania	0	-0.002***	1	-0.443***	9.612***	-0.002
Russia	-0.003*	-0.002***	1	0.144***	3.106***	0.001
Slovak						
Spain	-0.003	0	1	-1.052***	23.727	0.003
Ukraine	-0.037***	-0.008***	1	-0.821***	11.633***	0.029
Middle East & Africa						
Israel	-0.014***	-0.002	1	1.496***	-18.125***	0.012
Lebanon	-0.013***	-0.001	1	-0.092***	6.409***	0.012
Qatar	-	-		-	-	-
South Africa						
Turkey	-0.007***	-0.002	1	-0.127***	6.435***	0.005

This table shows the coefficient estimates of credit rating and CDS markets co-movement over the long run and short run. The VECM model is defined as:

$$\beta_1 CDS_t = -\gamma_1 - \beta_2 Rating_t - \varepsilon_{1,t}$$

$$\begin{bmatrix} \Delta CDS_t \\ \Delta Rating_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{1,t-1} + \sum_{i=1}^{p} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta CDS_{t-i} \\ \Delta Rating_{t-i} \end{bmatrix} + u_{1,t}$$

Where CDS_t is the log sovereign CDS spreads of a country at time t. $Rating_t$ is the average of foreign currency sovereign credit ratings of the country at time t of all three agencies. ΔCDS_t and $\Delta Rating_t$ refer to changes in CDS_t and $Rating_t$ at time t,. $\varepsilon_{1,t-1}$ is the one lag of $\varepsilon_{1,t}$. All variables are non-stationary and stationary in I(1). ***=p<0.01, **=p<0.05, *=p<0.1.

Table 12 VECM estimation for CDS and Outlook

Country	α_1	α_2	β_1	β_2	const	α_2 - α_1
Asia						
China	-0.004**	-0.001*	1	-2.76***	4.893***	0.003
Indonesia	-	-		-	-	-
Japan	-0.008**	-0.002***	1	-2.246***	2.892***	0.006
Kazakhstan	-	-		-	-	-
Korea	-	-		-	-	-
Malaysia	-	-		-	-	-
Philippines	-0.005**	-0.003**	1	-0.343***	5.301***	0.002
Thailand	-	-		-	-	-
Latin						
Argentina	-0.015***	0	1	-0.785***	6.207***	0.015
Brazil	-0.006***	0	1	-0.481***	5.219***	0.006
Chile	-	-		-	-	-
Colombia	-0.009***	-0.002	1	-0.694***	5.216***	0.007
Mexico	-0.003	-0.003***	1	-1.468***	4.571***	0
Panama	-0.006***	0		-0.01***	4.948***	0.006
Peru	-0.008***	-0.003*	1	-0.491***	5.18***	0.005
Venezuela	-	-		-	-	-
Europe						
Austria	-	-		-	-	-
Belgium	-	-		-	-	-
Bulgaria	-	-		-	-	-
Croatia	0.001	-0.002***	1	-1.941***	4.165***	-0.003
France	-	-		-	-	-
Greece	-	-		-	-	-
Hungary	0.002*	-0.003***	1	-2.995***	2.842***	-0.005
Ireland	-0.018***	-0.002***	1	-4.246***	2.881***	0.016
Italy	-	-		-	-	-
Poland	-	-		-	-	-
Portugal	-	-		-	-	-
Romania	-	-		-	-	-
Russia	-0.001	-0.002***	1	-0.663***	4.904***	-0.001
Slovak	-	-		-	-	-
Spain	-	-		-	-	-
Ukraine	-0.041***	-0.008***	1	-1.826***	5.943***	0.033
Middle East & Africa						
Israel						
Lebanon	-0.013***	-0.004		-0.034***	5.96***	0.011
Qatar						
South Africa	-	-		-	-	-
Turkey	-0.007***	-0.007	1	-0.143***	5.805***	0

This table shows the coefficient estimates of credit outlook and CDS markets co-movement over the long run and short run. The VECM model is defined as:

$$\beta_1 CDS_t = -\gamma_1 - \beta_2 Outlook_t - \varepsilon_{1,t}$$

$$\begin{bmatrix} \Delta CDS_t \\ \Delta Outlook_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{2,t-1} + \sum_{i=1}^{p} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta CDS_{t-i} \\ \Delta Outlook_{t-i} \end{bmatrix} + u_{2,t}$$

Where CDS_t is the log sovereign CDS spreads of a country at time t. $Outlook_t$ is the average of foreign currency sovereign credit outlooks of the country at time t of all three agencies. ΔCDS_t and $\Delta Outlook_t$ refer to the changes of CDS_t and $Outlook_t$ at time t. $\varepsilon_{2,t-1}$ *is* the error correction term of one lag of $\varepsilon_{2,t}$. All variables are non-stationary and stationary in I(1). Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

4.5.3 Spillover

The empirical results for cointegration and VECM analysis suggest that credit rating and outlook have strong impact on the spreads of their own country's CDS for most of the sample countries. Nevertheless, many other countries show no long-run relation nor join the error correction mechanism, which leads us to focus on the short-term interaction. One question that arises is whether sovereign CDS spreads react to rating changes in other countries. In this section, we extend the previous analysis and investigate potential spillover effects across countries. To test for the existence of spillover effects, we regress the sovereign CDS spread changes of a home country (ΔCDS_{it}^{h}) on the aggregate change in the rating/outlook of the other countries (ΔR_{it}^{nh} and ΔO_{it}^{nh})[24]. We control for past changes of explanatory variables (ΔCDS_{it-1}^{h}), using one lag[25]. The fixed effect panel regression is as follows:

$$\Delta CDS_{it}^{h} = \beta_1 \Delta CDS_{it-1}^{h} + \beta_2 \Delta R_{it}^{nh} + \beta_3 \Delta O_{it}^{nh} + \varepsilon_{i,t} \tag{13}$$

where ΔR_{it}^{nh} and ΔO_{it}^{nh} are the rating and outlooks changes by any agency regarding any other country in the sample. When any country (except for the home country) experiences a rating or outlook change, announced by any of the three rating agencies, ΔR_{it}^{nh} or ΔO_{it}^{nh} is set accordingly to be that change[26]. The subscripts i and t stand for the home country and time, respectively. The error term, $\varepsilon_{i,t}$, is an independently distributed random variable with zero mean and variance $\sigma_{i,t}^{2}$.

[24] The aggregate rating and outlook change, ΔR_{it}^{nh} and ΔO_{it}^{nh}, of the other countries is constructed as the sum of rating and outlook shift in all other countries.
[25] This lag specification follows previous literature, such as Kaminsky and Schmukler (2002) and Afonso et al. (2012).
[26] This is consistent with Kaminsky and Schmuler (2002). The reason for separating rating events from three credit rating agencies is that taking the average of the three agencies would underestimate the rating event effect.

Table 13 shows significant spillover effects from outlook announcement to sovereign CDS spreads. The lagged CDS spread changes are generally negative and statistically significant. An outlook upgrade of other countries by one notch on the scale decreases local CDS spread changes by 0.5, while the rating changes of other countries do not have much impact on local CDS spreads. The negative coefficients indicate that improvement in rating and outlook status narrows the CDS spreads. These results might be explained as investors responding to overall developments in the global financial environment, which is in line with Longstaff et al. (2011), who suggest CDS spread is more related to global factors. Moreover, CDS spreads are more sensitive to outlook changes than they are to rating changes, which is consistent with work suggesting that outlook announcements carry more information than rating events (Alsakka and ap Gwilym, 2012, Christopher et al., 2012).

4.5.3.1 Impact of initial credit quality

It is argued that spillover effects might depend on the initial credit qualities of the home countries (Ismailescu and Kazemi, 2010): the higher its credit quality, the less it is affected by external influences. To test the interaction effect of the credit quality of the target countries, we add two variables to Eq (13), the rating quality ($Rating_{it}^{h}$) and outlook quality ($Outlook_{it}^{h}$), as defined in Eq (1)(2). With such an adjustment, the fixed effect panel model becomes:

$$\Delta CDS_{it}^{t} = \beta_1 \Delta CDS_{it-1}^{h} + \beta_2 \Delta R_{it}^{nh} + \beta_3 \Delta O_{it}^{nh} + \beta_4 Rating_{it}^{nh} + \beta_5 Outlook_{it}^{nh} + \beta_6 \Delta R_{it}^{nh} * Rating_{it}^{h} + \beta_7 \Delta O_{it}^{nh} * Outlook_{it}^{h} + \varepsilon_{i,t} \quad (14)$$

where the interaction terms ($\Delta R_{it}^{nh} * Rating_{it}^{nh}$) and ($\Delta O_{it}^{nh} * Outlook_{it}^{nh}$) represent the interaction effect with its own credit status. From the results of the second column of Table 13, it can be concluded that the rating level of local government does not have much effect on spillover to the CDS market. Nevertheless, outlook qualities of the local sovereigns are able to influence these spillover effects at the 10% level. The lagged CDS spreads and global outlook changes are still strong determinants for the CDS spreads of home countries. Credit rating quality is strongly related to changes in CDS spreads, consistent with the VECM analysis. The results for interaction terms reveal that the rating quality of the home country does not have a significant influence on the spillover effect. This finding rejects the suggestion that higher credit quality would makes a country's CDS spreads immune to global influence, but is consistent with Afonso et al. (2012), who find no evidence of strong interaction between credit quality and rating events.

4.5.3.2 Rating and outlook changes by region of origin

Is the spillover effect is constrained within its own region or globally propagated? We next examine the existence of spillover at global level as well as regional level, examining for spillover effects of rating/outlook originating from different regions: Asia and Pacific, Latin America, Europe and Middle East & Africa in our sample. The rating/outlook changes are split into two groups according to their origin – same region or other region. We divide the rating and outlook variables, in Eq (13), into the regional and non-regional groups:

$$\Delta CDS_{it} = \gamma_1 \Delta CDS_{it-1} + \beta_1 \Delta R^{r}_{it} + \beta_2 \Delta R^{nr}_{it} + \beta_3 \Delta O^{r}_{it} + \beta_4 \Delta O^{nr}_{it} + \varepsilon_{i,t} \qquad (15)$$

where ΔR^{r}_{it}, ΔR^{nr}_{it}, ΔO^{r}_{it} and ΔO^{nr}_{it} are rating/outlook changes at time *t* by the three rating agencies. *r* represents credit change for a country belonging to the same geographic region as country *i*, while *nr* stands for credit events for countries in other regions.

Column 3 of Table 13 summarizes the estimations of rating and outlook spillover effects from four regions. Spillover effects are much stronger for credit rating/outlook changes within the same region than those from other regions. The lagged CDS spreads changes are strong determinants of present CDS spreads. A rating changes of one bp within-region leads to a decrease in log CDS spreads of 0.0023 bp. The out-of-region rating changes are shown to have no explanatory power on shifts in CDS spreads. Nevertheless, within-region outlook changes are proven to be strong drivers of CDS spread changes. A one bp upgrade in within-region outlook is able to trigger a CDS spread decrease of 0.0028 bp, while out-of-region outlook changes also have a significant impact on spread changes, -0.0018 bp. In general, the sovereign CDS spread changes are affected by within-region rating and outlook changes rather than out-of-region influences, and these findings are in line with studies on contagion (Corsetti et al., 2000, Kaminsky and Reinhart, 2000, 2003).

4.5.3.3 Spillover from the US market

The US market is believed to be a strong driving force in the international market. Christopher et al. (2012) report that the Chicago Board of Option Exchange‘s implied volatility of S&P 500 index options (VIX) is useful in explaining the intra-country/region stock and bond market co-movement. Longstaff et al. (2011) suggest that sovereign CDS spreads are more related to the US market rather than to local factors. Ismailescu and Kazemi (2010) examine the relation between sovereign CDS spread changes with trading and debt flow with the US. Pan and Singleton (2008a) find credit risk in developing markets is affected by US economic growth. Kaminsky and Reinhart (2003) find that the interest rate in the US is highly related to country risk and stock return in emerging markets.

In this section, we investigate the spillover effect from the US market by regressing Eq (15) on two explanatory variables from the US: the CBOE's VIX and the yield spread between the Moody's 30-year US Baa corporate bond and 6-month US T-bill.

$$\Delta CDS_{it} = \gamma_1 \Delta CDS_{it-1} + \beta_1 \Delta R_{it}^{r} + \beta_2 \Delta R_{it}^{nr} + \beta_3 \Delta O_{it}^{r} + \beta_4 \Delta O_{it}^{nr} + \delta_1 \Delta VIX_t + \delta_2 \Delta US\ Spread_t + \varepsilon_{i,t} \quad (16)$$

where the rating and outlook variables are rating/outlook changes at time *t* by the three rating agencies. Similar to Pan and Singleton (2008), VIX is the implied volatility of S&P 500 index options as a proxy for financial and economic uncertainty in the US and captures international investors' risk aversion. The US yield spread reflects US financial market development.

Table 13 column 4 shows the estimation results for Eq (16). The VIX is highly significant for all the countries in our sample, at the 1% level, with the coefficient at 0.0057. It is positively related to the sovereign CDS spreads; increase in the volatility of the S&P 500 leads to wider sovereign CDS spreads. The US yield spreads also have a substantial influence on the spreads of other nations. The spillover effect of rating and outlook changes from within-region countries remains significant, even after adjusting for the influence from the US. However, the weak impact from changes in rating and outlook of countries outside the region suggests that they contain no important information for determining local CDS spreads.

4.5.3.4 Before and after crises

It has been argued that financial markets tend to react excessively to sovereign rating/outlook changes during periods of crisis (Fender et al., 2012). We therefore explore the spillover effect of credit events to sovereign CDS markets in different business cycles.

NBER's Business Cycle Dating Committee announces the US business cycle of recession starts from December 2007 to June 2009. The subprime mortgage crisis became a global financial crisis after affecting almost all markets around the world. According to the Business Cycle Dating Committee for the euro area of the Center for Economic and Policy Research (CEPR), there have been two cyclical periods since 2004. The recession periods are 2008Q1 - 2009Q2 (part of the financial crisis) and 2011Q3 – 2012Q4 (the Eurozone debt crisis). Eight out of 17 Eurozone member countries have been in recession during this sovereign debt crisis, since the third quarter of 2011, led by Greece, Ireland, Italy, Portugal, Spain and Slovakia.

In order to examine the impact of rating and outlook during crisis times and tranquil times, we split the sample into two sub-samples: pre-crisis and crisis period; thus, we have the crisis period December 2007 - June 2009 and August 2011 – June 2012, and the pre-crisis period November 2004 – December 2007 and June 2009 – August 2011. Using panel regression with country-fixed effects, we re-estimate Eq (16) during pre-crisis period and crisis periods, separately.

The last two columns of Table 13 report estimation results for the two sub-samples. We find that, consistent with previous findings, past changes in sovereign CDS spreads could be used to estimate present changes in both pre-crisis and crisis period. The results reveal that CDS spreads are insensitive to changes in rating/outlook shifts within the same region, in the pre-crisis period. Furthermore, during crisis, CDS spreads respond only to regional outlook changes, at -0.0066 bp, rather than reacting to regional rating changes or rating/outlook changes outside their own region. One bp within-region outlook upgrade narrows the CDS spreads by 0.0066 bp during turmoil. On the other hand, rating and outlook changes from other regions show no significant impact on sovereign CDS spreads, in pre-crisis or crisis periods.

In terms of the US influence, our results suggest a strong positive spillover from the US market into CDS markets during both tranquil and turmoil periods. Increases in implied volatility of S&P 500 index options, VIX, levers the CDS spreads by 0.0071 bp (pre-crisis) and 0.005 bp (crisis), showing that market 'fear' could infect other countries. Moreover, higher US yield spreads decrease CDS spreads by 0.0411 bp during crisis periods. In general, the international spillover effect is much stronger during a crisis period, while sovereign CDS spreads are affected by regional outlook changes and the US market.

Table 13 Spillover effect

	Spillover	Interaction	Regional spillover	US spillover	Pre-crisis	Crisis
CDS changes 1st lag	-0.2001***	-0.2002***	-0.2001***	-0.1989***	-0.1876***	-0.234***
	[-55.8379]	[-55.8525]	[-55.8371]	[-55.9421]	[-43.7548]	[-36.8858]
Non-target Rating changes	-0.0008	-0.0025				
	[-1.504]	[-1.4414]				
Non-target Outlook changes	-0.0024***	-0.0026***				
	[-3.2118]	[-3.3218]				
Target Rating		0.0002				
		[0.7766]				
Target Outlook		0.0015*				
		[1.8938]				
Interaction rating		0.0001				
		[1.0265]				
Interaction outlook		0.0005				
		[0.8763]				
Rating regional			-0.0023**	-0.0019**	-0.0017	-0.001
			[-2.5267]	[-2.0729]	[-1.4686]	[-0.6742]
Outlook regional			-0.0038***	-0.0035**	-0.0014	-0.0066***
			[-2.6007]	[-2.4642]	[-0.7156]	[-3.0059]
Rating non-regional			0	0.0003	0.0012	0.0002
			[0.0029]	[0.4942]	[1.468]	[0.1426]
Outlook non-regional			-0.0018**	-0.0012	0	-0.002
			[-2.0153]	[-1.3847]	[-0.038]	[-1.4377]
VIX				0.0057***	0.0071***	0.005***
				[35.1124]	[23.4702]	[28.2857]
US yield Spread				0.0096***	-0.004	0.0411***
				[2.7018]	[-0.8921]	[7.3043]

This table reports fixed effect panel estimates of spillover with rating/outlook status interaction, regional effect, US spillover effect and crisis effect, individually. We add variables of credit quality of target countries and non-target countries and the interaction with rating changes in other countries to examine the credit quality effect on spillover effect. Regional and non-regional variables are constructed to capture the influence of region effect for rating and outlook respectively. The US spillover variables, VIX and US yield spreads are added to estimate the spillover from US markets. Moreover, the sample is separated into two sub-samples to analysis the reaction of CDS spreads to rating and outlook events in different business cycles. Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

Changes of rating and outlooks take the values of changes of any agency from any non-target country in the sample. When there exists a rating or outlook change announced by any of the three rating agencies for any of the non-target countries, ΔR_{it}^{nt} or ΔO_{it}^{nt} is set to be that change accordingly. The subscripts i and t stand for country and time, respectively. The error term, $\varepsilon_{i,t}$, is independently distributed random variable with zero mean and variance $\sigma_{i,t}^2$.

4.5.3.5 Tests of robustness

In the panel regression, we rejected the possibility of reverse causality, as in the previous lead-lag relation analysis. Another form of endogeneity applied to the correlation between the lagged dependent variable ΔCDS_{it-1}^{h} and the error term, which introduces biased estimators. To correct for this, we use the IV method or 2SLS panel regression with fixed country effects, suggested by Anderson and Hsiao (1982). Further lags of the dependent variable, ΔCDS_{it-1}^{h}, is used as instrument.

In the previous sections, the model is estimated by OLS. Considering that the time dimension of the panel has 1,974 observations, OLS estimates are unlikely to be biased. Nevertheless, the Anderson-Hsiao instrumental variables method can produce less biased estimates. These results could be used in the thesis as a check on the robustness of the OLS estimates.

The generalized method of moments (GMM), proposed by Arellano and Bond (1991), is generally used to estimate the dynamic panel regression. But the GMM dynamic panel model is designed for large numbers of cross-section units (large N) and few periods (T). Large T, small N means that the large number of instruments used could generate the over-identification problem, as the number of instruments produced will be quadratic in T.

As the table below shows, there is no significant different from the previous results, which indicates that the earlier conclusion is robust across regression methods. The only difference is that the spillover impact of credit rating is even weaker in this estimation. This highlights the persistent influence of credit outlook on international spillover. In addition, the rating quality of home country does have an impact on the spillover. Nevertheless, the major results are consistent with the previous analysis. Regional outlook and US factors are the most significant influences on international spillover, while the credit ratings of the home countries does not have much influence on such spillover. Compared with tranquil periods, sovereign CDS spreads become more sensitive to external factors – regional outlook changes and the US market – in crisis periods.

Table 14 Robustness test for spillover effects

	Spillover	Interaction	Regional spillover	US spillover	Pre-crisis	Crisis
CDS changes 1st lag	0.194***	0.194***	0.194***	0.205***	0.374***	-0.018
	(10.32)	(10.29)	(10.31)	(11.03)	(12.48)	(-0.91)
Non-target Rating changes	0.001	-0.004*				
	(1.31)	(-1.76)				
Non-target Outlook changes	-0.004***	-0.004***				
	(-3.20)	(-3.20)				
Target Rating		0.001*				
		(1.68)				
Target Outlook		0.001				
		(0.52)				
Interaction rating		0.000**				
		(2.28)				
Interaction outlook		0.001				
		(0.67)				
Rating regional			0.000	0.000	0.002	0.001
			(0.35)	(0.34)	(1.15)	(0.50)
Outlook regional			-0.006***	-0.005**	-0.001	-0.009***
			(-2.74)	(-2.26)	(-0.39)	(-2.59)
Rating non-regional			0.001	0.001	0.002*	0.001
			(1.44)	(1.41)	(1.84)	(0.45)
Outlook non-regional			-0.003*	-0.002	-0.002	-0.002
			(-1.94)	(-1.52)	(-0.98)	(-1.00)
VIX				0.007***	0.007***	0.006***
				(26.25)	(14.93)	(20.96)
US yield Spread				0.015**	-0.005	0.042***
				(2.24)	(-0.46)	(4.88)

This table reports fixed effect panel estimates of spillover with rating/outlook status interaction, regional effect, US spillover effect and crisis effect, individually. We add variables of credit rating of target countries and non-target countries and the interaction with rating changes in other countries to examine the credit rating effect on spillover effect. Regional and non-regional variables are constructed to capture the influence of region effect for rating and outlook respectively. The US spillover variables, VIX and US yield spreads are added to estimate the spillover from the US market. Moreover, the sample is separated into two sub-samples to analyse the reaction of CDS spreads to rating and outlook events in different business cycles. Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

Changes in rating and outlooks take the values of changes of any agency from any non-target country in the sample. When there exists a rating or outlook change announced by any of the three rating agencies for any of the non-target countries, ΔR_{it}^{nt} or ΔO_{it}^{nt} is set to be that change accordingly. The subscripts i and t stand for country and time, respectively. The error term, $\varepsilon_{i,t}$, is independently distributed random variable with zero mean and variance $\sigma_{i,t}^2$.

4.6 Spillover and contagion in the Eurozone debt crisis

We begin by illustrating broad reactions of CDS spread to bailout, at the time around the announcement date. As we have shown in the previous analysis, changes in credit rating and outlook in the home country, regional creditworthiness, along with spillover from the US, significantly affect sovereign CDS spread. We control for the spillover impact from credit rating and impact of the US market, and report econometric results from Granger causality, VAR/VECM and GIRF, for each bailout.

Our analysis is conducted by examining the effect of each rescue package, separately. For each rescue event, we consider the pre- and post-rescue sub-periods. Granger causality， cointegration tests, VECM/VAR and impulse response analysis are reported for both sub-periods Impulse response functions are obtained from VECM estimation for cointegrated series and from VAR when there is no long-run relation.

We perform the following Granger causality test for CDS spreads in both level and first difference in Eq (17)(18).

$$CDS_{i,t} = \alpha + \sum_{m=1}^{p} b_{i,m} CDS_{i,t-m} + \sum_{m=1}^{p} c_j CDS_{j,t-m} \tag{17}$$

$$CDS_{j,t} = \alpha + \sum_{n=1}^{p} CDS_{j,n} y_{t-n} + \sum_{n=1}^{p} c_j CDS_{i,t-n} \tag{18}$$

The lag length, *p*, is chosen by AIC for up to lag 12. The null hypothesis is that CDS spreads/changes of country *i* do not Granger-cause CDS spreads /changes in countries *j*.

With the results of the section 3.5, we are able to control the ratings and other external influences affecting sovereign CDS spreads. The Johansen's ML procedure VECM and VAR, with p-lags[27], is specified as below:

$$\beta_1 CDS_{i,t} = -\gamma_1 - \beta_2 CDS_{j,t} - \varepsilon_{1,t} \tag{19}$$

$$\begin{bmatrix} \Delta CDS_{i,t} \\ \Delta CDS_{j,t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{1,t-1} + \sum_{i=1}^{p-1} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta CDS_{i,t-i} \\ \Delta CDS_{j,t-i} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \\ \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \end{bmatrix} \begin{bmatrix} \Delta R_{it}^{h} \\ \Delta O_{it}^{h} \\ \Delta R_{it}^{r} \\ \Delta O_{it}^{r} \\ \Delta VIX_t \\ \Delta US\ Spread_t \end{bmatrix} + u_{1,t} \tag{20}$$

where $CDS_{j,t}$ is the logarithmized CDS spreads of the rescued country at time *t*. $CDS_{i,t}$ is the log-CDS spreads of the other country at time *t*. ΔCDS_t represent the changes of CDS_t. ΔR_{it}^{h} and ΔO_{it}^{h} are rating and outlook changes in the bailed-out countries, ΔR_{it}^{r} and ΔO_{it}^{r} are changes in rating and outlook for Eurozone region countries. As in the previous empirical test, VIX is the implied volatility of S&P 500 index options as a proxy for financial and economic uncertainty in the US market and captures international investors' risk aversion. The US yield spread reflects US financial market development. $u_{1,t}$ are non-autoregressive *i.i.d.* residuals, with zero mean and constant variance.

4.6.1 The reaction of CDS spreads to rescue packages

[27] *p* lags represent the optimal lags for the underlying VAR model; there are p-1 lags in the corresponding VECM model.

The reactions of CDS spreads are compared before and after each rescue plan, as average daily changes of log-CDS spread. Table 15 and Figure 3 show the average daily changes in CDS spreads for the bailed-out country and core European countries around each bailout.

The CDS spreads of all observed countries drop significantly after Greece's first bailout. The average change in CDS spread for Greece in the 7 days after the event is -0.093 bp, while the spread stands at 0.038 bp in the month before the rescue. Germany saw its daily changes in CDS spread tightens from -0.0081 bp (7 days before) to -0.0326 bp (7 days after). The "rescue" effect becomes weaker over a longer period, e.g. from -0.0939 bp to 0.0005 bp for Greece 30 days after the event. It could be said that the bailout plan was effective in saving Greece from default, by lowering its CDS spread significantly, while the spreads of core countries benefit from it as well. The 7-day spread change is slightly higher than before the bailout (-0.0249 bp vs -0.0282 bp).

Similarly for Ireland's bailout, the upward trend in CDS spread is reversed after its implementation. Furthermore, the bailout effect becomes weaker for the bailed country only in the longer term, while the credit risk of other countries continues to fall.

As for Portugal's bailout and Greece's second bailout, according to Figure 3 the spreads of these two bailed-out countries is not tightened by the bailout plan. On the contrary, it becomes even wider after the rescue plan is announced. The change in 7-day CDS spreads for Portugal surges from -0.0109 bp to 0.0222 bp after its bailout. The market shows the same reaction to Greece's second bailout (-0.0175 bp 7 days before to 0.0049 bp 7 days after). The CDS spreads of other European countries also widened after these two bailouts, when daily changes in spreads turn from negative to positive. This may indicate that these rescue plans did not achieve the aim of narrowing CDS spreads in a troubled country but nonetheless worsened the credit risk of all EU members.

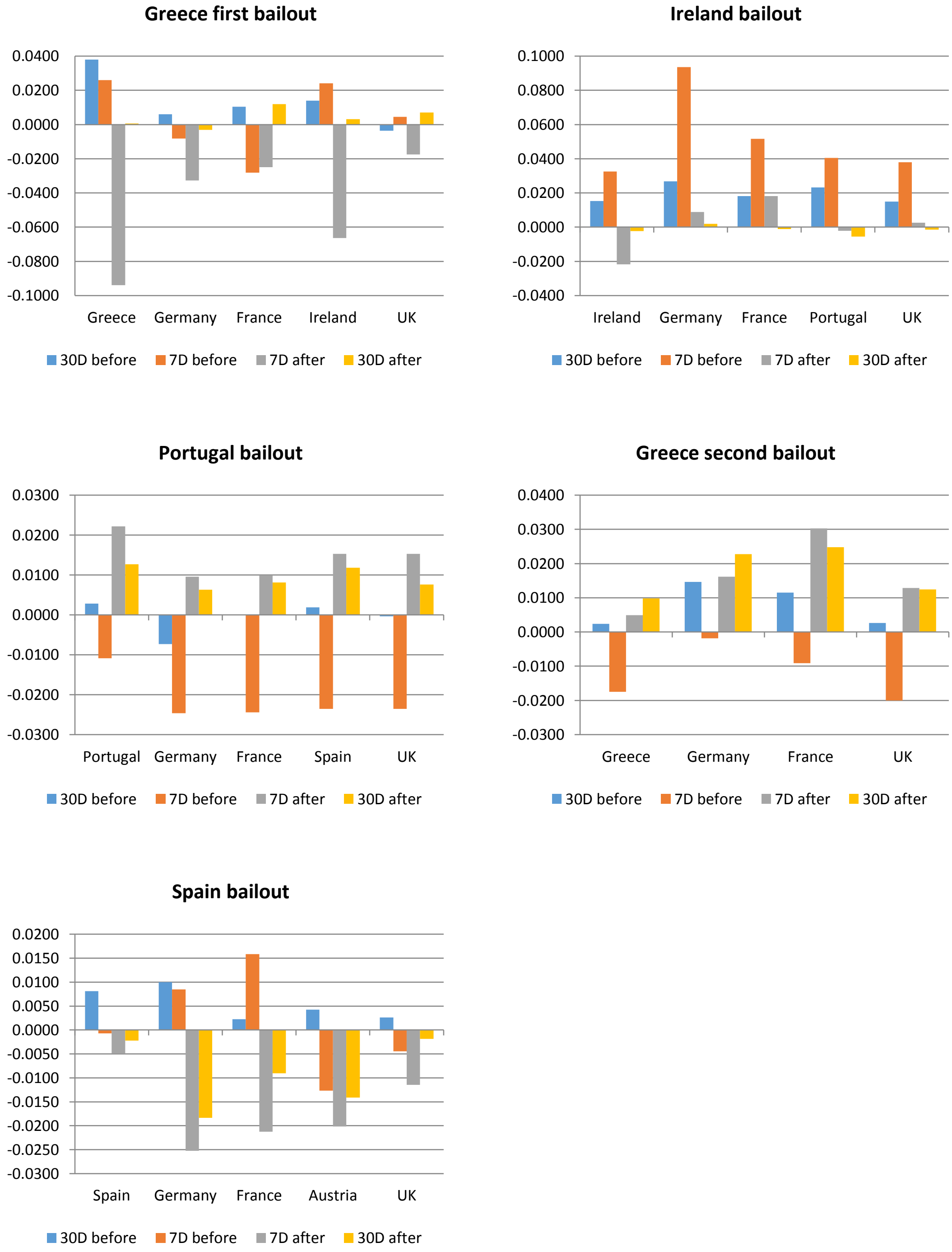
Spain's bailout, as the last rescue plan, proves to be effective in lowering the spreads for both Spain itself as well as "Core" countries.

Table 15 Average daily changes in CDS spreads around event dates

Date	Event	Countries	30D before	7D before	7D after	30D after
02/05/2010	Greece first bailout	Greece	0.0380	0.0261	-0.0939	0.0005
		Germany	0.0060	-0.0081	-0.0326	-0.0031
		France	0.0105	-0.0282	-0.0249	0.0120
		Ireland	0.0140	0.0241	-0.0664	0.0031
		UK	-0.0036	0.0045	-0.0174	0.0071
28/11/2010	Ireland bailout	Ireland	0.0153	0.0326	-0.0217	-0.0022
		Germany	0.0267	0.0936	0.0089	0.0020
		France	0.0182	0.0517	0.0181	-0.0010
		Portugal	0.0233	0.0405	-0.0021	-0.0056
		UK	0.0150	0.0380	0.0025	-0.0015
16/05/2011	Portugal bailout	Portugal	0.0028	-0.0109	0.0222	0.0127
		Germany	-0.0073	-0.0246	0.0095	0.0063
		France	0.0000	-0.0244	0.0099	0.0081
		Spain	0.0019	-0.0236	0.0153	0.0118
		UK	-0.0003	-0.0236	0.0153	0.0076
21/07/2011	Greece second bailout	Greece	0.0024	-0.0175	0.0049	0.0098
		Germany	0.0146	-0.0018	0.0162	0.0227
		France	0.0115	-0.0091	0.0303	0.0248
		UK	0.0027	-0.0201	0.0129	0.0124
09/06/2012	Spain bailout	Spain	0.0081	-0.0007	-0.0050	-0.0022
		Germany	0.0100	0.0085	-0.0252	-0.0183
		France	0.0023	0.0158	-0.0213	-0.0090
		Austria	0.0043	-0.0127	-0.0202	-0.0141
		UK	0.0026	-0.0044	-0.0115	-0.0019

This table presents the average daily changes in CDS spreads around event dates for the following time windows: 30 days before, 7 days before, 7 days after, 30 days after. The countries are selected for their different characteristics and importance to the regional economy.

Figure 3 Average daily changes in CDS spreads around bailout dates



The figure presents the average daily changes in CDS spreads around bailout dates for the following time windows: 30 days before, 7 days before, 7 days after, 30 days after. The countries are selected for their different characteristics and importance to the regional economy, while some are directly affected by the policy intervention.

4.6.2 Bailout analysis

In this section, we present the results for Greece's first and second bailouts, Ireland's bailout, Portugal's bailout and Spain's bailout. These bailouts have unique features in the Eurozone debt crisis. Greece was the first and worst affected nation, while the bailout for Spain, as the healthiest nation of the PIIGS, was caused by the Spanish government having to rescue its national banks in financial crisis, and was affected by the anxiety over Greece debt. We try here to identify any changes in the interdependence of sovereign credit risk before and after interventions during the Eurozone sovereign debt crisis.

4.6.2.1 Greece's bailouts

Greece had two bailout plans, from 2 May 2010 and 21 July 2011. In this study, we focus on the interactions between Greece and 9 other countries in the Eurozone, within three time periods: before the first bailout, between bailouts, and after the second bailout. The Granger causality test result is shown first in Table 16, while the cointegration test is presented in Table 43. VECM and generalized impulse response function results are depicted in Table 17 and Figure 4.

4.6.2.1.1 Granger causality and cointegration

In Table 16, before the first bailout, Granger causality test results suggests that GR Granger-cause almost all other countries, except for the UK, while AU, BG, FR, DE, IR, IT and SP could Granger cause GR. It is consistent with our assumption that GR information is crucial in determining other countries, before bailout.

Before the first bailout, cointegration test results suggest there is a long-term relationship between GR and all the other countries, except FR and UK. The long-term cointegration relation, e.g. with Germany, may be written as:

$$CDS_{DE,t} = 1.637 + 0.341 * CDS_{GR,t} + \varepsilon_{1,t}$$

That is, a 1 bp change in the spreads for Greece leads to an adjustment in CDS spreads for Germany of 0.341 bp over the long run. The significant β shows a strong long-run equilibrium relationship between Greece and other countries, while the negative sign of β confirms that, as the credit risk of GR is lowered, the CDS spreads of other cointegrated countries become narrower in the long run. A positive sign for β would suggest sovereign CDS spreads move in the opposite direction. The spreads of BG, DE, IR, IT, PT and SP are negatively related to GR, over the range -0.341 bp to -1.005 bp. The result suggests that GR is in a long-term relationship with all PIIGS nations, but not with most core nations.

Before intervention, the α coefficients suggest that GR adjusts at a rate of -0.037 bp in the relation GR-AT, and GR is also involved in the error correction mechanism within BG, DE and IT. In contrast, all the other countries, except for AT, adjust at a rate of -0.052 bp, -0.037, -0.014, -0.057, -0.084 and -0.081 bp respectively, in their relation with GR. Comparing the adjustment speed of the bailed-out and other countries, we find that $|\alpha_{GR}| > |\alpha_{Core}|$, suggesting that GR is faster in adjustment speed before the first bailout, in the case of AT and DE. From α coefficients of GR and other countries under stress, we have $|\alpha_{GR}| < |\alpha_{other\ PIIGS}|$, showing a significant sensitivity to the spread for Greece among the other PIIGS before the bailout.

After the first bailout plan was activated, Greece could only Granger-cause AT and PT. Nevertheless, spread changes in all core countries are able to Granger-cause Greek spread. This suggests that the influence from Greece was weakened after first bailout, while the influence of the core countries was enhanced.

Moreover, the long-term relation with GR alters after the bailout, as DE, IR and PT are no longer cointegrated with GR. Nevertheless, FR and UK begin to be in stable long-term relationships with GR spread. The α coefficients show that all cointegrated countries adjust to the long-term equilibrium after the bailout, with the exception of AT. Moreover, Greece actively adjusts in its relations with all the other EU members. Comparing the magnitude of the adjustment speed coefficients, $|\alpha_{GR}|$ is close to or greater than the $|\alpha_{core}|$, indicating a high sensitivity of GR spreads to the those of the core nations. For GR and the other PIIGS, the same relation is found, as $|\alpha_{GR}| < |\alpha_{other\ PIIGS}|$.

Comparing the interactions between GR and each country for the pre- and post-periods, Greece adjusted faster in its relation with AT, but slower with BG, while other core countries do not have a constant cointegration relation with GR.

After the second bailout plan was implemented, only IR and PT are Granger-caused by GR spread. But most core nations, BG, FR and DE, are able to Granger-cause GR. This is further support for Greece being the information receiver, rather than the source, after bailout.

In terms of long-term relations, the results show that GR is cointegrated with AT, FR, DE, UK, PT and SP. From the α coefficient results, it is found that all the countries that cointegrated with Greece try to eliminate deviation from their long-term relationship, at the 5% level, except for Germany. Nevertheless, Greece only reacts to deviation from its relationship with Austria at the 5% level.

Comparing the magnitude of α coefficients before and after the second Greek bailout, $|\alpha_{other}|$ is larger in the period after that bailout, for all the significant α. This result indicates that AT, FR, UK, PT and SP adjusted faster after bailout. The less significant α_{GR} shows that Greece did not react as quickly as before.

Table 16 Granger causality for Greece's first and second bailouts

Variables	Period	PIIGS not GC others		others not GC PIIGS	
		test	Pr()	test	Pr()
Panel A Greece first bailout					
GR - AT	before	**3.159**	**0.025**	**4.819**	**0.003**
	after	**8.365**	**0.000**	**7.062**	**0.001**
GR - BG	before	**4.329**	**0.014**	**2.899**	**0.057**
	after	0.248	0.780	**2.345**	**0.098**
GR - FR	before	**7.025**	**0.001**	**5.031**	**0.007**
	after	1.804	0.166	**5.649**	**0.004**
GR - DE	before	**11.871**	**0.000**	**5.337**	**0.005**
	after	0.622	0.431	**4.838**	**0.029**
GR - UK	before	1.704	0.184	2.08	0.127
	after	1.265	0.284	**3.863**	**0.022**
GR - IR	before	**5.279**	**0.006**	**3.331**	**0.037**
	after	1.487	0.228	0.439	0.645
GR - IT	before	**5.019**	**0.007**	**2.435**	**0.09**
	after	0.723	0.486	**7.327**	**0.001**
GR - PT	before	**3.292**	**0.039**	0.731	0.482
	after	**2.588**	**0.077**	0.947	0.389
GR -SP	before	**6.841**	**0.001**	**2.533**	**0.081**
	after	0.699	0.498	**9.328**	**0**
Panel B Greece second bailout					
GR - AT	before				
	after	1.494	0.228	1.726	0.182
GR - BG	before				
	after	0.943	0.392	**2.813**	**0.063**
GR - FR	before				
	after	1.639	0.198	**2.514**	**0.084**
GR - DE	before				
	after	1.050	0.373	**3.444**	**0.018**
GR - UK	before				
	after	0.613	0.543	1.939	0.148
GR - IR	before				
	after	**2.541**	**0.082**	**2.802**	**0.064**
GR - IT	before				
	after	1.001	0.370	1.846	0.162
GR - PT	before				
	after	**3.853**	**0.005**	0.519	0.722
GR - SP	before				
	after	0.431	0.650	2.304	0.103

The Granger causality test provides direction of information flows, when the lag is chosen by BIC. Its F-test results are summarized. The test equation is $y_t = \alpha + \sum_{i=1}^{5} b_i y_{t-i} + \sum_{j=1}^{5} c_j x_{t-j}$, the null hypothesis is that x does not Granger-cause y, $c_j = 0$ for all j. If the statistic exceeds the 10% critical value (indicated by bold type), the null hypothesis of absence of Granger causality is rejected.

Table 17 VECM for Greece first and second bailout

Variables	Period	α_{others}	α_{PIIGS}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}	α_{16}	α_{21}	α_{22}	α_{23}	α_{24}	α_{25}	α_{26}	β_{others}	β_{PIIG}
Panel B Greece second																	
GR - AT	before	-0.019	-0.037***	0.01	-0.013	0.007	-0.001	-0.024	0	-0.038***	0.045	0.015	-0.041**	-0.034	0.005*	1	0.03
		[-1.591]	[-3.149]	[0.66]	[-0.311]	[0.378]	[-0.03]	[-0.454]	[-0.178]	[-2.634]	[1.159]	[0.827]	[-1.985]	[-0.663]	[1.936]		[0.18]
	after	-0.011	-0.041***	0	-0.001	0.003	0	-0.123***	0.003*	-0.004	0.013	0.002	0.01	-0.072	0.01***	1	0.383**
		[-0.982]	[-3.457]	[-0.032]	[-0.046]	[0.572]	[0.023]	[-2.799]	[1.894]	[-0.741]	[0.544]	[0.426]	[0.787]	[-1.601]	[7.275]		[2.33]
GR - BG	before	-0.052***	-0.041**	-0.024*	0.038	0.008	-0.009	-0.066	0.005**	-0.04***	0.051	0.007	-0.046**	-0.038	0.004*	1	-0.368***
		[-2.967]	[-2.129]	[-1.848]	[1.066]	[0.446]	[-0.471]	[-1.399]	[2.099]	[-2.741]	[1.307]	[0.352]	[-2.214]	[-0.718]	[1.674]		[-3.46]
	after	-0.028**	-0.021**	-0.004	0.072**	0.005	0.016	-0.157***	0.006***	-0.004	0.009	0.001	0.008	-0.07	0.01***	1	-0.161
		[-2.366]	[-2.109]	[-0.746]	[2.544]	[0.979]	[1.12]	[-2.971]	[3.767]	[-0.796]	[0.364]	[0.146]	[0.648]	[-1.543]	[7.349]		[-0.69]
GR - FR	before																
	after	-0.029**	-0.041***	0.001	0.029	0.003	0.026**	-0.141***	0.006***	-0.003	0.016	0	0.009	-0.071	0.01***	1	0.041
		[-2.161]	[-3.168]	[0.233]	[1.139]	[0.699]	[1.99]	[-2.976]	[4.355]	[-0.609]	[0.646]	[0.097]	[0.714]	[-1.568]	[7.32]		[0.27]
GR - DE	before	-0.037**	-0.053***	-0.012	0.06*	-0.01	-0.007	0.058	0.005**	-0.041***	0.057	0.007	-0.046**	-0.041	0.004*	1	-0.341***
		[-2.351]	[-3.099]	[-0.931]	[1.732]	[-0.609]	[-0.36]	[1.251]	[2.117]	[-2.835]	[1.488]	[0.38]	[-2.209]	[-0.803]	[1.726]		[-3.09]
	after																
GR - UK	before																
	after	-0.028**	-0.047***	0.003	0.031	0.001	0.01	-0.071*	0.008***	-0.004	0.014	0.002	0.012	-0.071	0.01***	1	0.109
		[-2.229]	[-3.114]	[0.6]	[1.525]	[0.381]	[1.009]	[-1.878]	[6.54]	[-0.765]	[0.587]	[0.425]	[1.008]	[-1.57]	[7.412]		[0.73]
GR - IR	before	-0.014**	-0.001	-0.029***	0.015	-0.014	-0.023	-0.005	0.005**	-0.041***	0.049	0.006	-0.046**	-0.027	0.005*	1	-0.763
		[-2.585]	[-0.196]	[-2.619]	[0.521]	[-0.953]	[-1.486]	[-0.137]	[2.376]	[-2.797]	[1.244]	[0.307]	[-2.164]	[-0.51]	[1.877]		[-0.96]
	after																
GR - IT	before	-0.084***	-0.054**	-0.01	0.042	0	-0.019	-0.037	0.007***	-0.042***	0.053	0.007	-0.047**	-0.04	0.004*	1	-0.37***
		[-3.399]	[-2.048]	[-0.699]	[1.158]	[0.009]	[-0.948]	[-0.755]	[2.855]	[-2.897]	[1.376]	[0.361]	[-2.226]	[-0.764]	[1.75]		[-5.24]
	after	-0.037***	-0.034***	-0.004	0.06*	0.001	0.028*	-0.223***	0.01***	-0.004	0.013	0.002	0.012	-0.067	0.01***	1	-0.042
		[-2.705]	[-3.386]	[-0.542]	[1.815]	[0.155]	[1.695]	[-3.649]	[5.061]	[-0.785]	[0.548]	[0.345]	[0.986]	[-1.488]	[7.326]		[-0.23]
GR - PT	before	-0.055**	-0.003	-0.011	0.02	-0.005	-0.021	-0.048	0.005**	-0.04***	0.046	0.008	-0.046**	-0.022	0.005*	1	-1.005***
		[-2.375]	[-0.11]	[-0.753]	[0.541]	[-0.261]	[-1.065]	[-0.973]	[2.15]	[-2.747]	[1.169]	[0.401]	[-2.176]	[-0.428]	[1.827]		[-11.48]
	after																
GR -SP	before	-0.081***	-0.046	0.004	0.038	-0.009	-0.05**	-0.026	0.005**	-0.04***	0.05	0.006	-0.047**	-0.031	0.004*	1	-0.448***
		[-3.025]	[-1.644]	[0.279]	[1.009]	[-0.476]	[-2.446]	[-0.525]	[2.175]	[-2.773]	[1.282]	[0.306]	[-2.244]	[-0.606]	[1.688]		[-6]
	after	-0.046***	-0.036***	-0.005	0.035	0.003	0.022	-0.214***	0.008***	-0.004	0.011	0.001	0.008	-0.067	0.01***	1	-0.195
		[-2.855]	[-2.825]	[-0.819]	[1.121]	[0.569]	[1.383]	[-3.713]	[4.455]	[-0.897]	[0.446]	[0.206]	[0.687]	[-1.497]	[7.217]		[-1.24]

Panel B Greece second																	
GR - AT	after	-0.17***	0.117**	-0.01	0.152	-0.016	0.017	0.142	0.008***	-0.054**	-0.048	0.014	-0.029	-0.164	0.003	1	-0.186***
	2nd	[-3.371]	[2.481]	[-0.447]	[0.835]	[-1.129]	[0.585]	[1.269]	[2.904]	[-2.484]	[-0.279]	[1.057]	[-1.076]	[-1.563]	[1.02]	-	[-3.81]
GR - BG	after																
	2nd																
GR - FR	after	-0.057**	0.053	-0.024	0.145	-0.009	0.008	-0.141*	0.007***	-0.042*	-0.067	0.009	-0.02	-0.12	0.002	1	0.109
	2nd	[-2.06]	[1.404]	[-1.476]	[1.136]	[-0.904]	[0.402]	[-1.781]	[3.677]	[-1.925]	[-0.389]	[0.647]	[-0.695]	[-1.124]	[0.916]	-	[1.03]
GR - DE	after	-0.018	-0.038*	-0.008	0.093	-0.006	0.019	-0.134	0.004*	-0.09***	-0.122	0.01	-0.033	-0.103	0.002	1	0.124*
	2nd	[-1]	[-1.695]	[-0.336]	[0.704]	[-0.647]	[0.912]	[-1.623]	[1.838]	[-3.02]	[-0.728]	[0.836]	[-1.227]	[-0.98]	[0.633]	-	[1.69]
GR - UK	after	-0.137***	0.049	-0.007	0.048	-0.007	0.009	-0.025	0.003*	-0.042*	-0.06	0.01	-0.027	-0.132	0.002	1	-0.038
	2nd	[-2.726]	[0.553]	[-0.604]	[0.494]	[-0.922]	[0.552]	[-0.405]	[1.819]	[-1.911]	[-0.346]	[0.787]	[-0.954]	[-1.224]	[0.792]	-	[-1.28]
GR - IR	after																
	2nd																
GR - IT	after																
	2nd																
GR - PT	after	-0.137***	-0.001	0.018	0.051	-0.007	0.002	-0.001	0.001	-0.101***	-0.097	0.013	-0.03	-0.144	0.003	1	-0.098***
	2nd	[-3.468]	[-0.017]	[1.205]	[0.622]	[-1.164]	[0.131]	[-0.023]	[0.9]	[-3.229]	[-0.554]	[0.958]	[-1.076]	[-1.324]	[0.984]	-	[-2.63]
GR - SP	after	-0.132***	0.116*	-0.019	0.136	-0.007	0.007	-0.155**	0.002	-0.045**	-0.088	0.01	-0.027	-0.161	0.001	1	0.023
	2nd	[-3.406]	[1.779]	[-1.5]	[1.313]	[-0.874]	[0.429]	[-2.453]	[1.543]	[-2.118]	[-0.51]	[0.804]	[-0.995]	[-1.517]	[0.558]	-	[0.12]

This table shows the coefficients estimates of CDS markets co-movement in the long run and short run. The VECM model is defined as:

$$\beta_1 \mathrm{CDS}_{i,t} = -\gamma_1 - \beta_2 \mathrm{CDS}_{j,t} - \varepsilon_{1,t}$$

$$\begin{bmatrix} \Delta \mathrm{CDS}_{i,t} \\ \Delta \mathrm{CDS}_{j,t} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \varepsilon_{1,t-1} + \sum_{i=1}^{p-1} \begin{bmatrix} \varphi_{1,i} & \varphi_{2,i} \\ \varphi_{3,i} & \varphi_{4,i} \end{bmatrix} \begin{bmatrix} \Delta \mathrm{CDS}_{i,t-i} \\ \Delta \mathrm{CDS}_{j,t-i} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \\ \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \end{bmatrix} \begin{bmatrix} \Delta R_{it}^{h} \\ \Delta O_{it}^{h} \\ \Delta R_{it}^{r} \\ \Delta O_{it}^{r} \\ \Delta \mathrm{VIX}_t \\ \Delta \mathrm{US\ Spread}_t \end{bmatrix} + u_{1,t}$$

Where $CDS_{j,t}$ is the ln-CDS spreads of rescued country at time *t*. $CDS_{i,t}$ is the logarithmized CDS spreads of other country at time *t*. ΔCDS_t represent the changes of CDS_t. The β matrix describes the long-run relationship between sovereign CDS spreads. The α_1 and α_2, speed of adjustment, measure the speed of each market adjusting to long-run equilibrium. If α is significantly negative, the corresponding market would adjust back to the long-run equilibrium, driven by the error correction term ε. ΔR_{it}^{h} and ΔO_{it}^{h} are rating and outlook changes in the bailed-out countries, ΔR_{it}^{r} and ΔO_{it}^{r} are Eurozone regional rating and outlook changes. As previous empirical test, VIX is the implied volatility of S&P 500 index options as a proxy for financial and economic uncertainty in the US market and captures international investors' risk aversion. The US yield spread reflects US financial market developments. $\varepsilon_{1,t-1}$ and $\varepsilon_{2,t-1}$ are the error correction terms, corresponding to the lag one of $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$, which are the residuals of cointegration equations. When the cointegration relation is rejected for pairs of CDS spreads, the VECM estimation shows as blank. ***=p<0.01, **=p<0.05, *=p<0.1.

4.6.2.1.2 Impulse response

The results of impulse response function analysis of Greece's bailouts are plotted in Figure 4. The red solid lines represent the impulse responses before the first bailout, while the blue dashed line indicates the impulse responses in the period between the first and second bailout. The yellow dot-dash lines describe the responses after the second bailout plan was implemented. The impulse response of Greece and another 9 countries are plotted in 4 graphs (2×2), such as Greece and Austria: GR->GR (upper-left), the response of GR to shock in GR; AR->GR (lower-left), the response of GR to shock in AT; GR->AR (upper-right), the response of AR to shock in GR; AT->AT (lower-right), response of AT to shock in AT.

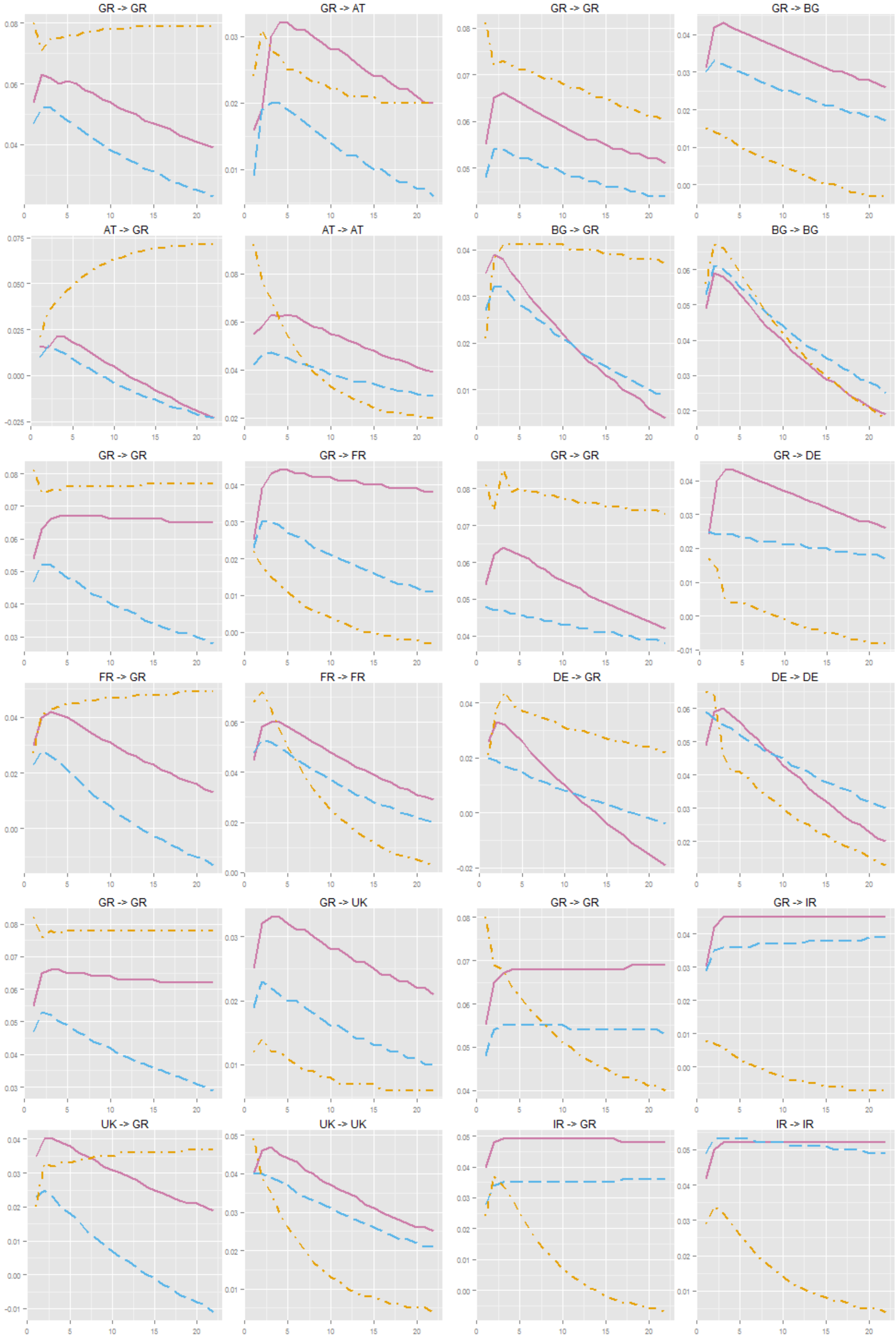
Before the first bailout, a shock in other countries temporarily affects CDS spreads for Greece (response sharply decreases). Similar but weaker responses are found for the period after first bailout. However, this reaction becomes stronger and permanent after the second bailout (response stays at the same level or higher). The only exceptions are IR and PT, where Greece's responses in the first two periods are permanent and significant, but become much weaker and temporary after the second bailout.

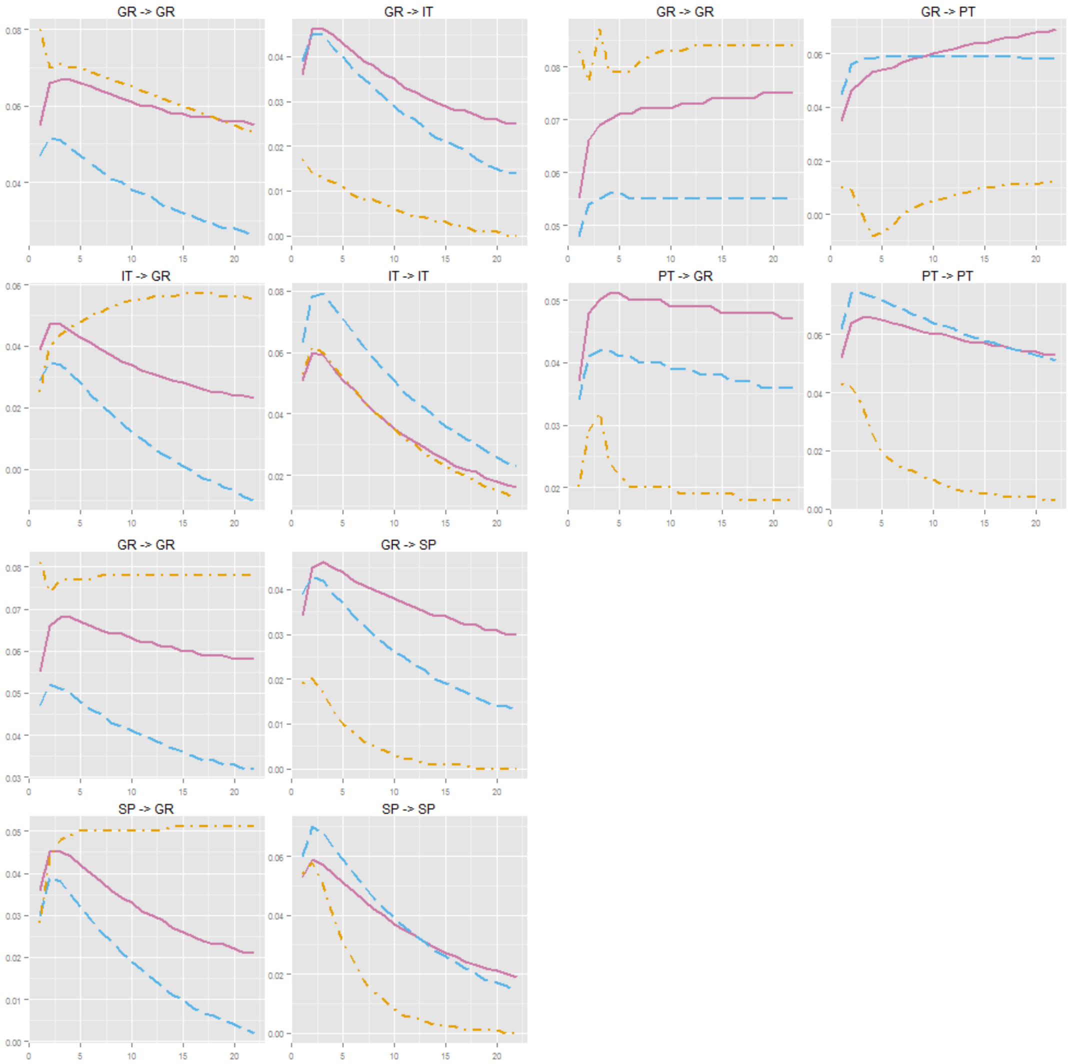
In terms of the Eurozone countries' response to a shock in Greece, the reactions are permanent and stable before any EU intervention, with the exceptions of shocks from BG, UK and IT (peaks at day 2 or day 3 and declining thereafter). Nevertheless, the influence of Greece on other sovereign states becomes short term and limited after the first bailout. Only IR and PT show permanent reactions to shocks from Greece. After the second bailout, we find no "peaking" effect and the reaction is much weaker compared with previous periods. AT is the only country to react more strongly than before (decreases steeply after peaking at day 2). For all three periods, the EU members' responses to Greek shock are temporary and decrease significantly shortly after day 2.

In addition, national reactions to countries' own shocks seem to follow a common pattern after the second bailout for Greece: peaks in the short-term (day 2) and then dropping steeply. Nevertheless, it is worth noticing that Greece was significantly less sensitive to its own shock after the first bailout.

The differences between the influences of Greece's first and second bailouts are also revealed by the IRF. In fact, there is no significant difference in terms of the core's response to Greek shock (spillover from Greece to core), which is further weakened after each bailout. As for Greece's response to shock in a core country, we argue that it is strengthened in the case of AT, BG and DE, although not by much. After 10-20 days, the response of AT, BG, and DE after the first bailout exceeds the response in the pre-bailout period. To explain why the effect is not as significant as for the second bailout, we can make two suggestions: (1) as the first Greek bailouts was essentially unprecedented, the core countries were not yet much exposed to the credit risk of PIIGS (the public-to-public risk transfer was not complete), and investors were less sensitive to the credit risk changes of the cores; and (2) the first bailout was short and proved insufficient, which led to another bailout plan. The IMF admitted its original 2010 bailout programme for Greece was insufficient and served as a "holding operation" that allowed the euro area to fortify itself against financial disaster (WSJ, 2013). Moreover, it failed to put an end to the fear of an unruly Greek default.

Figure 4 GIR for Greece 1st and 2nd bailout





This figure presents the generalized impulse responses for Greece's first and second bailouts. The dynamic between GR and AT, BG, FR, DE, UK, IR, IT, PT and SP are plotted as a group of four, 2×2. e.g., the four graphs on top left panel show the GIRF for Greece and Austria respectively: GR (impulse variable) -> GR (response variable); GR (impulse var.) -> AT (response var.); AT (impulse var.) -> GR (response var.); AT (impulse var.) -> AT (response var.).

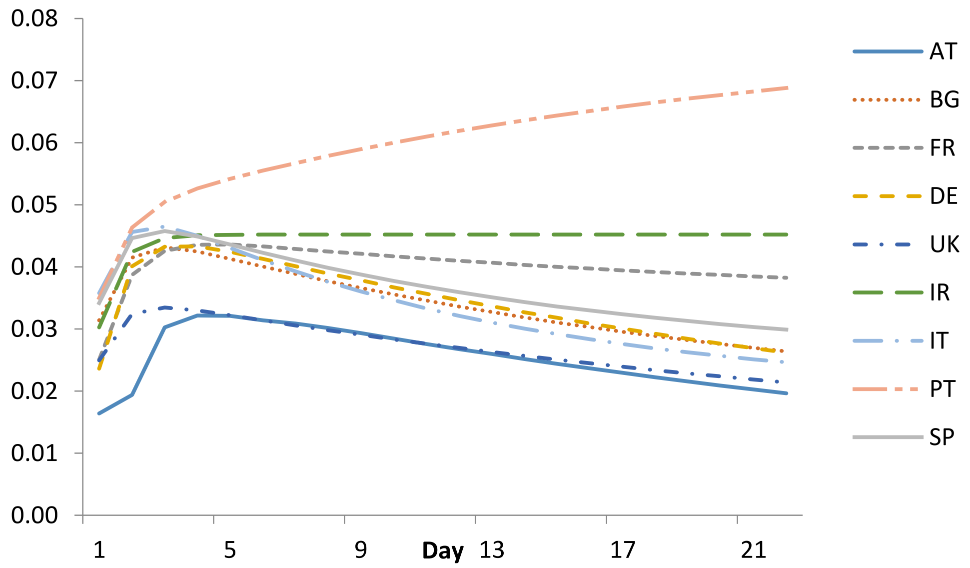
Note: X-axis: number of days after the shock generated from the impulse variable. Y-axis: response to a one standard deviation shock in impulse variable. Red solid lines: impulse responses before the first bailout. Blue dashed line: impulse responses in the period between the first bailout and second bailout. Yellow dot-dash lines: responses after the second bailout plan activated.

4.6.2.1.3 Cross-country analysis

Figure 5 shows the response of EU countries to shocks in Greece, before Greece's bailout, over 22 days. The impact of shock in Greece is significant and permanent for all the countries over the long run. Although the responses of most countries cluster around 0.03 bp, PT and IR spreads are exceptionally sensitive to Greek shock. As the next bailed-out countries, GR spread development contains extra information for determining their spreads.

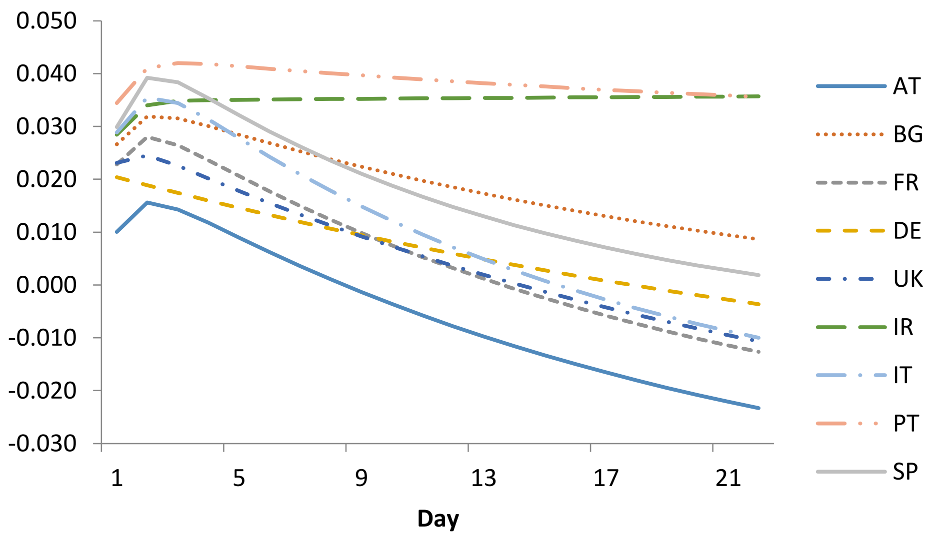
Figure 6 and Figure 7 describe the Greek response to shock from other EU members, after Greece's first and second bailouts, respectively. The response of Greek spread is higher for PT and IR shocks, while others only have weaker and temporary influence after Greece's first bailout. The higher sensitivity of spreads for Greece could be caused by the public finance imbalances and high debt level in Portugal and Ireland, which were the next two governments to require financial support. Investor confidence in Greece is largely affected by the development of PT and IR spreads, e.g. whether they could be rescued by the EU and IMF. Furthermore, after the second bailout, the impulse responses of GR to core nations are more significant, led here by AT shock. Interestingly, the former strongest sources, PT and IR, have the least impact on Greece after its second bailout, when the spreads of PT and IR were no longer the information source for Greece after both had been rescued. It is worth noticing that the other two PIIGS states, Italy and Spain, had a significant long-term influence on Greek spreads (behind Austria) after the bailout. This might be explained by highly volatile government spreads – in turn caused by domestic high debt and the possibility of further financial aid. Conversely, the core nations with large investments in the bailout are closely linked to the development of spreads for Greece. Greece's spreads become more sensitive to the core members by linking the Greek credit risk to the creditworthiness of the core countries.

Figure 5 Response of EU country spreads to a GR shock, before bailout



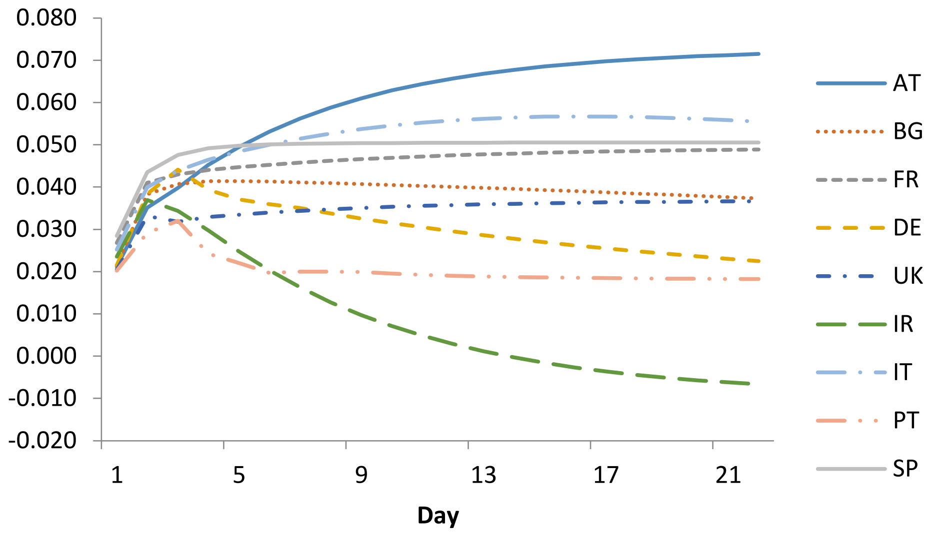
This figure depicts the response of other EU nations to a Greece shock, before its bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while IR, IT, PT and SP are the group of PIIGS (bottom four in legend).

Figure 6 GR response to shocks from other nations, after GR 1st bailout



This figure depicts the GR response to shock from other EU countries, after GR 1st bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while IR, IT, PT and SP are the group of PIIGS (bottom four in legend).

Figure 7 GR response to shocks from other nations, after GR 2nd bailout



This figure depicts the GR response to shock from other EU countries, after GR 2nd bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while IR, IT, PT and SP are the group of PIIGS (bottom four in legend).

4.6.2.1.4 Discussion

As the trigger of the Eurozone sovereign debt crisis, Greece had the highest deficit-GDP ratio (12.7%) and debt-GDP ratio (130%) in 2009 among all members. Following worsening financial markets, the EU agreed on a €110bn rescue package for Greece on 1 May 2010. This bailout payment was scheduled to be paid in several disbursements from May 2010 to June 2013. However, with the continued worsening of the Greek debt crisis, from 21 July 2011 to 21 February 2012, Greece requested a further €130bn bailout fund from the EU, along with a 50% government bond haircut, with the bailout funds mainly supported by the core European countries, especially Germany and France. The detail of the bailout was not ratified until February 2012, making the whole period after the second bailout a turbulent time. The first bailout package totalled €110 billion, of which the IMF contributed €30bn and the Eurozone the other €80bn. Germany's share of that €80bn was €22.4bn (28%) while France was responsible for €16.8bn. Shortly after the aid was announced, Greek government debt was restructured, meaning "default" on its debt.

Before the bailout, investors were most concerned with the development of Greek spread, since it contains important information: the possibility of future financial aid. This argument is supported by Granger causality test results, which show that Greek spread could Granger-cause most of the spread for other countries in Europe. Also, the IRF analysis shows that a shock from Greece has a significant and permanent impact on the CDS spreads of most other countries. Therefore, our Hypothesis 1 is supported.

The bailout plan binds the spread of a bailed-out country to the creditworthiness of those paying for that support. Hypothesis 2 suggests a higher reliance of PIIGS spreads on those countries that contribute to the bailout, because of the extra risk exposure and liability. Nevertheless, the causality test result contradicts this proposal, as Greece could Granger-cause only the spreads for AT after the first Greek bailout and for none of the core countries after the second bailout. Moreover, the VECM result implies that Greece reacted to deviations more actively after its first bailout. The IRF results further underline a reduced short-term response to a GR shock, after each bailout, although GR shock has the strongest impact on AT and the UK after the second bailout across countries. Thus, Hypothesis 2 is rejected by our results.

Through the credit guarantee provided by the healthy nations in the EU, investors in Greek bonds and CDS would be more sensitive to changes in the credit status of countries financing this bailout, mainly core nations. We would therefore expect a greater influence from the spreads of core countries on Greece after a bailout (H3). After the first Greek bailout, spread changes in all core countries are able to Granger-cause Greek spreads. Most still remain in the causality relation with Greece after second bailout. Moreover, a shock from the core countries has a significant and permanent effect on Greek spreads, especially after the second bailout. Thus, we have evidence in favour of H3. It is worth noticing that the sensitivity to the core countries might amplify the Greek debt crisis when credit issues of core countries emerge.

As for H4, before intervention the important information contained in spreads for Greece leads to the exceptional influence of a Greek shock on PT and IR spreads (next to be bailed-out, and with a poor fiscal outlook), while the influences on others are clustered. In return, after the first Greek bailout, PT and IR exceed all the other spreads and become the dominant driving force in Greek spreads, since they would experience bailouts in this period. Furthermore, in the turmoil of the second bailout, PT and IR shock become the least important in affecting GR, which have been rescued by the EU, while the core nations with "new" information have larger control. These findings support our H4.

To sum up, we find contagion emerging from Greek spreads and spillover into other EU countries before bailout, while core countries adjust to correct the deviation. The Granger causality test results suggest that Greece could Granger-cause most other countries but its influence is weakened after bailout. This supports H1 by discovering the existence of spillover effects from Greece to other EU countries, while spillover in the other direction is much weaker. The Granger causality test and impulse response analysis fails to support H2 as they find weaker and only temporary reactions to Greek shock after the first and second bailouts. However, we find strong evidence for H3, where development of core European countries' spreads begins to play an increasingly important role in Greece's spread, after each round of financial aid. H4 is partly supported in the case of Greece's first bailout, while in Greece's second bailout period, as a period of turmoil rather than a 'normal' post-bailout period, Greece shows higher sensitivity to its own spread. Our findings therefore support H4: the more information (bad fiscal outlook and financing the bailout) a country's spread contains, the closer its relation is with the bailed-out nation, no matter whether it is a PIIGS or a core country.

4.6.2.2 Ireland bailout

On 28 November 2010, Ireland reluctantly took a bailout of €85 billion from the IMF, the European Commission and European Financial Stabilisation Mechanism (EFSF). The analysis is conducted for the pre-bailout and post-bailout period, including: Granger causality test in Table 18, cointegration test in Table 44 and VECM and IRF in Table 19 and Figure 8.

4.6.2.2.1 Granger causality and cointegration

Before the bailout, for the short-term relationship, we find that the spread for Ireland could Granger-cause AT, DE, GR, IT and PT. Two are core European nations. This is partly in line with the suggestion of spillover from IR to the cores before intervention. In addition, the causality test of the opposite direction shows all countries were able to Granger-cause changes in IR, except for BG.

The cointegration test shows that a long-term relationship exists only with AT, DE, UK and IT, in the pre-bailout period. A 1 bp change in the Ireland spread could lead to an adjustment in Germany CDS spread of 0.044 bp. The adjustment speed, the α coefficient, suggests that, of the four cointegrated pair of countries, all of them adjust to correct error, while IR provides the stochastic trend in the long-run relation in the error correction mechanism. $|\alpha_{other}|$ is generally close to or larger than $|\alpha_{IR}|$, indicating that these four countries adjust back to equilibrium faster than IR, in the pre-intervention period. This result supports our H1.

After bailout, IR is able to Granger-cause more core countries, AT, FR, DE and UK, indicating increased influence on the cores after bailout. Moreover, the fact that most countries are also able to Granger-cause changes in IR leads to the conclusion that IR is strongly affected by international markets over the short run, especially those of the core nations. However, the cointegration test shows no cointegration for IR with any country, suggesting that there is no stable long-run relation between IR and others.

Table 18 Granger causality test for the Ireland bailout

Variables	Period	PIIGS not GC others		others not GC PIIGS	
		test	Pr()	test	Pr()
IR - AT	before	**3.993**	**0.002**	**3.176**	**0.008**
	after	**5.759**	**0.000**	1.288	0.274
IR - BG	before	1.599	0.134	1.407	0.201
	after	1.175	0.312	**2.471**	**0.012**
IR - FR	before	1.576	0.180	**2.902**	**0.022**
	after	**2.716**	**0.001**	**2.522**	**0.003**
IR - DE	before	**4.395**	**0.001**	**3.058**	**0.01**
	after	**5.129**	**0.000**	**3.2**	**0.013**
IR - UK	before	0.339	0.561	**4.321**	**0.038**
	after	**1.765**	**0.081**	**1.969**	**0.048**
IR - GR	before	**3.947**	**0.000**	**4.202**	**0**
	after	1.561	0.133	**1.801**	**0.074**
IR - IT	before	**3.620**	**0.000**	**2.454**	**0.01**
	after	1.322	0.230	**4.896**	**0**
IR - PT	before	**2.212**	**0.052**	**2.312**	**0.043**
	after	**4.688**	**0.001**	**3.455**	**0.008**
IR - SP	before	0.943	0.453	**2.914**	**0.013**
	after	1.005	0.431	**6.358**	**0**

The Granger causality test provides direction of information flows, when the lag is chosen by AIC. Its F-test results are summarized. The test equation is $y_t = \alpha + \sum_{i=1}^{5} b_i y_{t-i} + \sum_{j=1}^{5} c_j x_{t-j}$, the null hypothesis is that x does not Granger-cause y, $c_j = 0$ for all *j*. If the statistic exceeds the 10% critical value (indicated by bold type), the null hypothesis of absence of Granger causality is rejected.

Table 19 VECM for the Ireland bailout

Variable	Perio	α_{others}	α_{PIIGS}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}	α_{16}	α_{21}	α_{22}	α_{23}	α_{24}	α_{25}	α_{26}	β_{other}	β_{PIIG}
IR - AT	before	-0.031** [-2.744]	-0.033** [-3.047]	0.001 [0.031]	0 [-0.013	0.005 [0.641]	-0.002 [-0.146	-0.068 [-1.675	0.001 [0.806]	-0.025 [-1.593	0.009 [0.32]	-0.016** [-2.411]	-0.021 [-1.451	-0.073 [-1.891	0.007** [4.56]	1	-0.14 [-0.98
	after															-	-
IR - BG	before															-	-
	after															-	-
IR - FR	before															-	-
	after															-	-
IR - DE	before	-0.03*** [-2.671]	-0.018* [-1.667]	-0.014 [-0.848	0.009 [0.299]	-0.01 [-1.492	0 [0.027]	0.005 [0.116]	0.008** [5.149]	-0.023 [-1.464	0.006 [0.19]	-0.018** [-2.727]	-0.018 [-1.243	-0.057 [-1.479	0.006** [4.337]	1	0.044 [0.21]
	after															-	-
IR - UK	before	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	0*** [0]	1	0 [0.54]
	after															-	-
IR - GR	before															-	-
	after															-	-
IR - IT	before	-0.019** [-2.686]	0.001 [0.145]	-0.011 [-0.627	0.012 [0.357]	-0.009 [-1.177	0.003 [0.159]	-0.06 [-1.393	0.01*** [6.112]	-0.025 [-1.61]	0.008 [0.262	-0.018** [-2.658]	-0.019 [-1.313	-0.07* [-1.824	0.006** [4.173]	1	0.242 [0.94]
	after															-	-
IR - PT	before															-	-
	after															-	-
IR - SP	before															-	-
	after															-	-

This table shows the coefficients estimates of CDS markets co-movement in long-run and short run. The VECM model is defined in Eq 19 and 20. The β matrix describes the long-run relationship between sovereign CDS spreads. The α, speed of adjustment, measure the speed of each market adjusting to long-run equilibrium. If α is significantly negative, the corresponding market would adjust back to the long-run equilibrium, driven by the error correction term ε. When the cointegration relation is rejected for pairs of CDS spreads, the VECM estimation would show as blank. Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

4.6.2.2.2 Impulse response

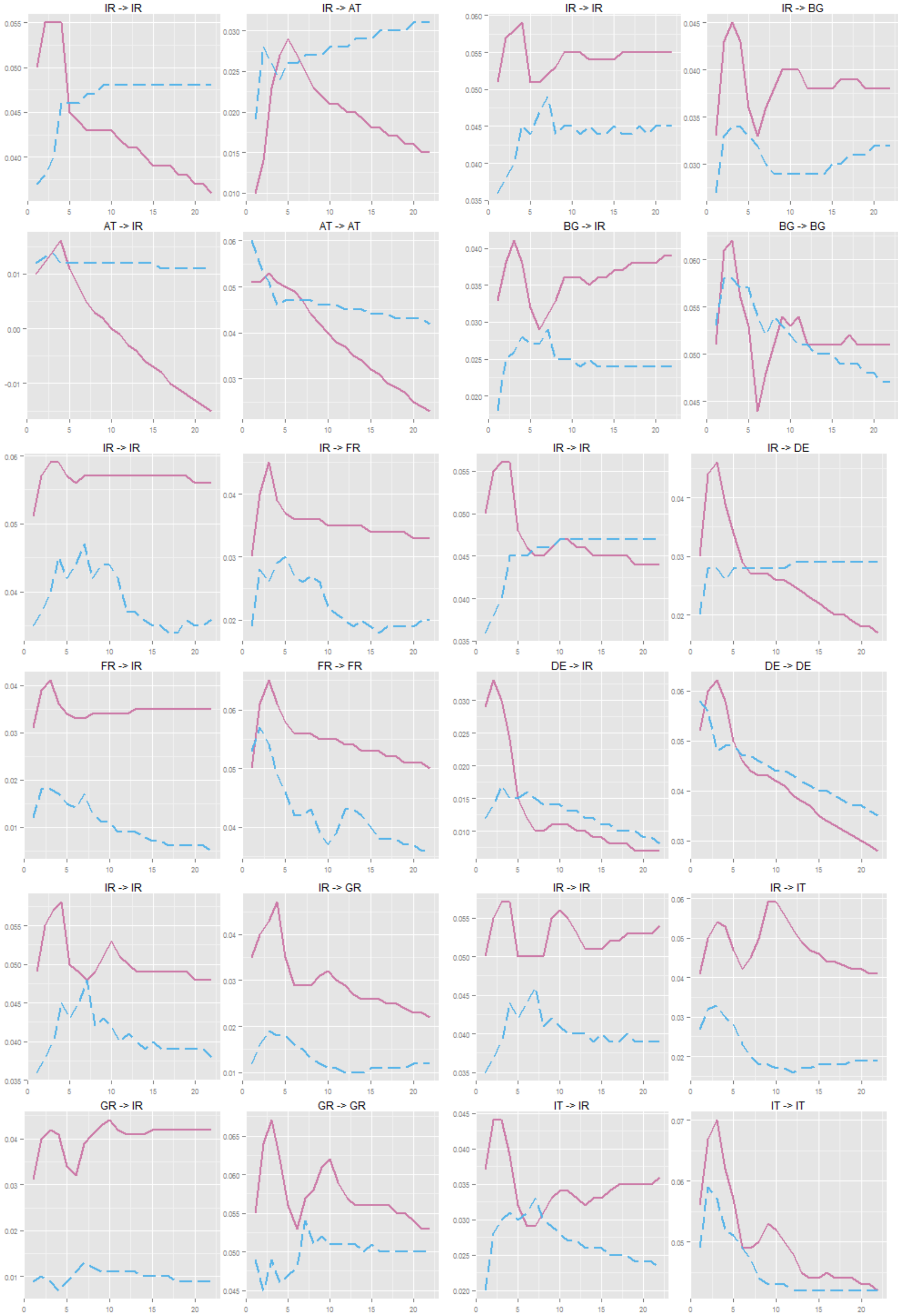
The impulse responses analysis, depicted in Figure 8, shows the interdependence between the Ireland spread and the spreads of other countries, in the pre- and post-bailout periods[28]. The graph in the upper-right corner of each panel indicates the reaction of EU countries to an Ireland shock. In the pre-bailout period, an IR shock stably and significantly affects all other countries, while DE and GR are temporarily affected. In the post-bailout period, an IR shock is able to influence all the core nations permanently; the effects on AT and DE exceeds those evident in the pre-bailout period after day 5 of the post-bailout period.

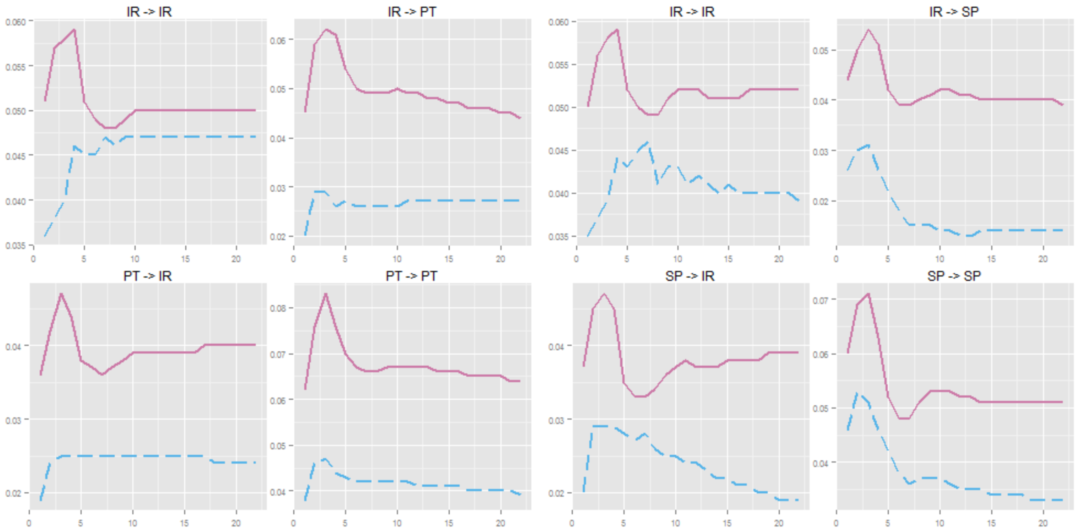
As for the response of IR to shock from other countries, in the pre-bailout period, IR is strongly and permanently affected by BG, FR, GR, IT, PT and SP. In the post-bailout period in all cases the effect is weaker. Conversely, the formerly weak sources, AT and DE shock, show increased influence on IR after the bailout.

Moreover, in terms of response to an internal shock, IR is highly affected by an IR shock before financial aid. But the sensitivity of IR spread to domestic shock is lower after the bailout. In addition, Austria and Germany again show stronger reaction to shocks from themselves after bailout, while the impacts are generally weaker for the others.

[28] The UK-IR relation is not shown in the Figure 8, since the IRF analysis leaves no appropriate data in the pre-bailout period.

Figure 8 GIRF for Ireland bailout





This figure presents the generalized impulse responses for the Ireland bailout. The dynamic between IR and AT, BG, FR, DE, GR, IT, PT and SP is plotted as a group of four, 2×2. e.g., the four graphs in the top left panel show the GIRF for Ireland and Austria respectively: IR (impulse variable) -> IR (response variable); IR (impulse var.) -> AT (response var.); AT (impulse var.) -> IR (response var.); AT (impulse var.) -> AT (response var.).

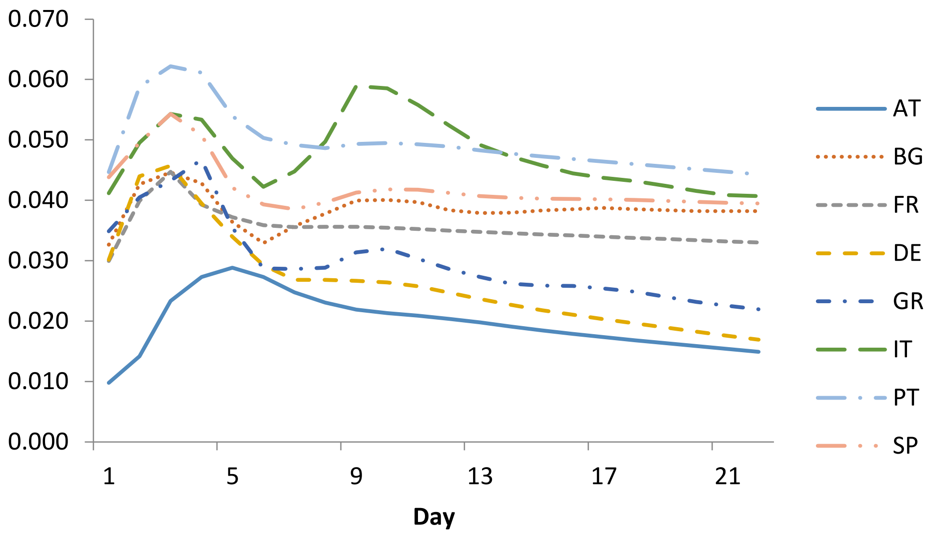
Note: X-axis: number of days after the shock generated from the impulse variable. Y-axis: response to a one standard deviation shock in the impulse variable. Red solid lines: impulse responses before bailout. Blue dashed line: impulse responses after bailout plan activated.

4.6.2.2.3 Cross-country analysis

Figure 9 shows the impulse response of EU countries to IR shock over 22 days before Ireland's bailout. A stable and permanent impact from IR shock can be found for most of the countries, led by PT and IT, while SP comes in third. The PT response could be led by the worsened expectation on PT debt, which required bailout after the Ireland bailout. In addition, IT, as the largest of the PIIGS economies, was a constant concern. On the other hand, the core nations, especially AT and DE, were less sensitive to IR shock before intervention. A pattern is found in the response to IR shock: those countries with a healthier fiscal outlook and little "new" information were less influenced. Specifically, the relatively low response for GR could be caused by its recent bailout, which is not as informative as before, with a better prospect of Greece paying its debt.

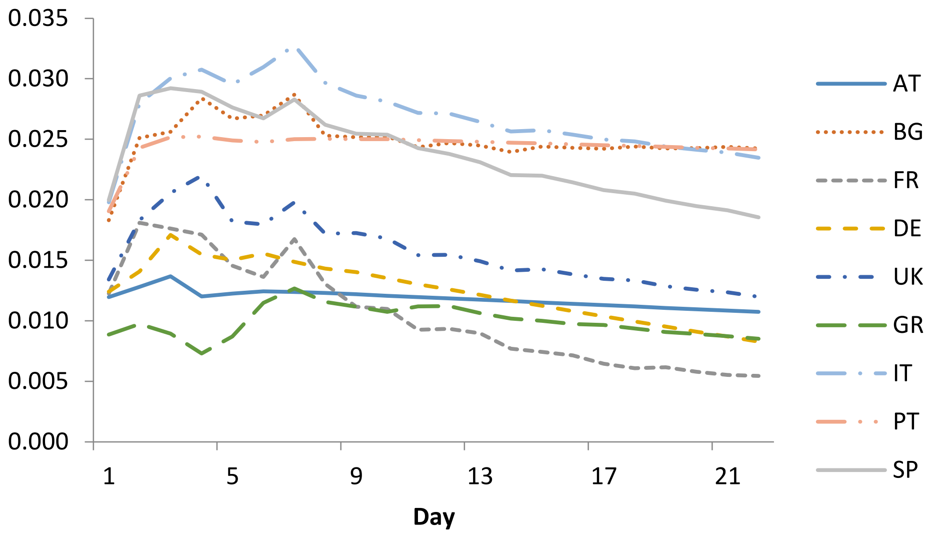
Figure 10 describes the IR response to shock from other EU members for 22 days in the post-bailout period. IR response to external shock is long term and continuing for most countries. PT is the most influential source over the long run, at 0.025 bp, while FR is the least crucial country affecting IR spread, at 0.005 bp. There is an interesting finding that the UK is the second most affected by IR shock, which is surprising considering its isolated role in the Eurozone rescue. However, since the Ireland bailout was the only one to which the UK contributed, the result is reasonable and interesting. It is consistent with o H3. Overall, the impact on IR spread is stronger for PIIGS nations than for core states. The long-run responses of two groups of countries generally cluster for each group, with the exception of Belgium and Greece. PT, IT and SP are three important PIIGS nations facing bailout in the forthcoming post-bailout period, which are shown as the driving forces in IR spreads. Although Belgium is one of the cores, it had the third highest debt-GDP ratio in Eurozone, at 100%. The concern of spillover from others makes its spread behave like that for the PIIGS. In addition, the recent bailout for GR leads to a less informative GR spread, which leads to a lower influence on IR.

Figure 9 EU country spreads in response to IR shock, before bailout



This figure depicts the response of other EU nations to Ireland shock, before its bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, and DE (top four in legend), while GR, IT, PT and SP are the group of PIIGS (bottom four in legend).

Figure 10 IR response to shock from other EU countries, after bailout



This figure depicts the IR response to shock in other EU nations, after its bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE, and UK (top five in legend), while GR, IT, PT and SP are the group of PIIGS (bottom four in legend).

4.6.2.2.4 Discussion

Different from Greece, which was trapped in sovereign debt crisis from government overspending, Ireland's debt crisis was caused by the government providing guarantees for six Irish banks. After the bursting of the property bubble in 2008, these Irish banks lost hundreds of billions euros. In order to save its major banks from collapse, the government introduced a bank guarantee scheme. It ended up with extensive losses. On 28 November 2010, the Irish government required assistance from the EU and IMF, and requested a €85 bn bailout fund, €67.5 bn of which was provided by the EFSF, the EFSM and the IMF, while €17.5 bn was from Irish pension funds and the UK, Denmark and Sweden.

The Granger causality test finds that the IR spread could Granger-cause AT, DE, GR, IT and PT, partly supporting the proposition that Ireland had influence on the spreads of other nations in the short run. Over the long run, the cointegration analysis shows IR led AT, DE, UK and IT. In addition, the IRF finds IR shock has a significant and permanent influence on most countries, which supports our H1.

Our Hypothesis 2 suggests a greater influence of PIIGS spreads on other countries after bailout, because the financing plan makes the cores more exposed to the credit risk of the bailed-out country. AT, FR, DE and the UK being Granger-caused by IR spreads supports our hypothesis, although there is no long-term cointegration relation between IR and any other nations. Furthermore, the IRF results underline a weaker reaction to IR shock for most countries, except for AT and DE. These findings lead to the conclusion that only some PIIGS, as well as Austria and Germany, are more affected by changes in the Ireland spread.

Whether the credit guarantee by other EU nations leads to higher sensitivity of Ireland to these countries is examined by H3. That most countries were able to Granger-cause IR highlights that IR is highly sensitive to the international markets over the short run. Moreover, AT and DE shock had a stronger and permanent effect on IR after the bailout, while no similar pattern was found in the relation with other cores. This partly supports our Hypothesis 3, and also indicates a country-specific characteristic.

For H4, a pattern is found in the response to IR shock: those countries with a healthier fiscal outlook (AT and DE) and little “new” information (GR) were less influenced, and the more risky nations (PT and IT) were more closely related to developments in IR. A similar pattern is found for the post-intervention period, as PT, IT and SP were risky PIIGS facing bailout, and were the driving forces in IR spreads. In addition, although Belgium is not a PIIGS country, its high debt-GDP ratio meant the country had crucial information for IR spread. The country-specific characteristic is well explained by the results, as higher information content leads to tighter relations with the bailed-out nation.

Combining the results from above, H1, H2, and H3 are supported by our results, in the case of Austria and Germany. The unique behaviour of AT and DE in their relations with IR, as well as in the GR bailout, is caused by their specific economic situations. Austria and Germany were countries with low debt-GDP ratios in the EU, at 69% and 74% in 2010, respectively. Their budget deficit-GDP ratios were also lower than those of most other EU members, at 4.5% and 4.2%, respectively. The fiscal health of AT and DE made them more closely related to IR spread among the cores. The country-specific characteristic in H4 is therefore well supported, as higher information content leads to tighter relations with the bailed-out nation.

4.6.2.3 Portugal bailout

On 16 May 2011, the EU and IMF approved a €78bn bailout for Portugal. The deal gives three-year loan of up to €78 billion, equally shared by the European Financial Stabilisation Mechanism (EFSM), the European Financial Stability Facility (EFSF) and the IMF. Our sample period is divided into two parts: pre-bailout and post-bailout periods. The Granger causality test results of its relationship with 9 other countries are presented in Table 20, the results of the cointegration test are shown in Table 45, with VECM and IRF in Table 21 and Figure 11.

4.6.2.3.1 Granger causality and cointegration

In the pre-bailout period, we find that changes in spreads for Portugal could Granger-cause those for all the core countries: AT, BG, FR, DE and UK. Ireland was the only one of the PIIGS whose spreads were Granger-caused by Portugal's spread. Conversely, PT is Granger-caused by all PIIGS countries, but not those of the core countries, with the exceptions of AT and DE.

Moreover, the cointegration result shows that Portugal is cointegrated with all core countries over the long run, except France. For example, a 1 bp change in the Portugal spreads could leads to an adjustment in Germany's CDS spread by 0.063 bp over the long run. In addition, α coefficient in Table 21 underlines that all the cointegrated core nations adjust back to the long-run equilibrium with Portugal at the 5% level. Meanwhile, PT makes adjustment only in its relation with AT, DE and GR, at -0.04 bp, -0.031 bp and 0.035 bp. These results indicate the leading role of PT as the source of spillover before intervention. Comparing the magnitude of adjustment speed, we find that $|\alpha_{AT}| = 0.019 < 0.039 = |\alpha_{PT}|$, which reflects that PT adjusts more quickly. BG and IT were the fastest countries in price adjustment in the relation with PT before bailout, $|\alpha_{BG}| = 0.029$ and $|\alpha_{IT}| = 0.034$.

After the announcement of the Portugal bailout plan, the short-term relation between Portugal and core countries changes as BG, DE and UK are no longer Granger-caused by PT, while PT has larger impact on all PIIGS nations. Moreover, only BG Granger-causes PT, while the all PIIGS countries Granger-cause PT, as in the pre-bailout period. It suggests a weakened influence for Portugal's spreads on the cores.

The β coefficients suggest that DE and UK are not in a long-term relation with PT, while FR and SP begin to be cointegrated with Portugal. AT, FR, GR, IT and SP adjust to long-run relations with Portugal at the 5% level, in the post-bailout period. Meanwhile, PT adjusts to long-run equilibrium only with BG and SP at the same significance level. Comparing the α coefficients with the previous period, we have a more rapid response to deviation from equilibrium from AT, while the other α coefficients of the core countries are either insignificant or not comparable.

Table 20 Granger causality test for Portugal bailout

Variables	Period	PIIG not GC others		others not GC PIIG	
		test	Pr()	test	Pr()
PT - AT	before	**3.806**	**0.002**	**5.041**	**0**
	after	**5.938**	**0.003**	0.4	0.671
PT - BG	before	**2.019**	**0.074**	1.048	0.389
	after	0.264	0.768	**6.121**	**0.002**
PT - FR	before	**4.343**	**0.002**	0.732	0.57
	after	**4.862**	**0.008**	1.102	0.333
PT - DE	before	**2.909**	**0.004**	**4.047**	**0**
	after	0.722	0.577	1.811	0.126
PT - UK	before	**2.225**	**0.065**	1.474	0.209
	after	0.287	0.751	0.837	0.434
PT - GR	before	1.340	0.229	**3.665**	**0.001**
	after	**4.820**	**0.008**	**3.705**	**0.025**
PT - IR	before	**2.969**	**0.012**	**2.2**	**0.053**
	after	**3.881**	**0.004**	**3.712**	**0.006**
PT - IT	before	1.927	0.105	**3.177**	**0.014**
	after	**3.994**	**0.019**	**7.918**	**0**
PT - SP	before	1.100	0.359	**4.335**	**0.001**
	after	**3.130**	**0.045**	**8.108**	**0**

The Granger causality test provides direction of information flows, when the lag is chosen by AIC. Its F-test results are summarized. The test equation is $y_t = \alpha + \sum_{i=1}^{5} b_i y_{t-i} + \sum_{j=1}^{5} c_j x_{t-j}$, the null hypothesis is that x does not Granger-cause y, $c_j = 0$ for all *j*. If the statistic exceeds the 10% critical value (indicated by bold type), the null hypothesis of absence of Granger causality is rejected and emphasized in bold.

Table 21 VECM for Portugal bailout

Variables	Period	α_{others}	α_{PIIGS}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}	α_{16}	α_{21}	α_{22}	α_{23}	α_{24}	α_{25}	α_{26}	β_{others}	β_{PIIG}
PT - AT	before	-0.019**	-0.039***	0.011	-0.005	-0.001	0.002	-0.062*	0.002	0.002	-0.001	-0.012**	0.005	-0.088**	0.01***	1	0.112
		[-2.147]	[-3.909]	[1.155]	[-0.265]	[-0.176]	[0.146]	[-1.754]	[1.195]	[0.221]	[-0.04]	[-2.148]	[0.345]	[-2.227]	[6.576]		[1.59]
	after	-0.031**	0.006	0.003	-0.065	0	0	-0.038	0.007***	-0.004	-0.035	-0.003	-0.002	-0.078**	0.002**	1	-1.509***
		[-2.565]	[0.868]	[0.146]	[-0.677]	[0.007]	[0.031]	[-0.658]	[4.267]	[-0.362]	[-0.63]	[-1.103]	[-0.316]	[-2.392]	[2.378]		[-8.32]
PT - BG	before	-0.029**	-0.019	0.017*	0.019	-0.01**	0.012	-0.081**	0.006***	0.003	0.002	-0.012**	0.01	-0.085**	0.01***	1	-0.504***
		[-2.59]	[-1.474]	[1.843]	[0.938]	[-2.041]	[1.003]	[-2.257]	[4.806]	[0.32]	[0.092]	[-2.152]	[0.688]	[-2.082]	[6.375]		[-5.57]
	after	-0.005	0.017**	-0.003	-0.069	0	0.002	-0.2***	0.005***	-0.004	-0.028	-0.003	-0.004	-0.078**	0.002**	1	-1.542***
		[-0.521]	[2.441]	[-0.15]	[-0.884]	[-0.098]	[0.163]	[-4.315]	[3.821]	[-0.334]	[-0.514]	[-1.166]	[-0.463]	[-2.409]	[2.289]		[-8.16]
PT - FR	before																-
																	-
	after	-0.04***	-0.001	0.013	-0.111	0.002	-0.004	-0.239***	0.006***	-0.003	-0.04	-0.003	-0.002	-0.076**	0.002**	1	-0.927***
		[-3.269]	[-0.103]	[0.731]	[-1.319]	[0.547]	[-0.349]	[-4.794]	[4.071]	[-0.259]	[-0.721]	[-1.106]	[-0.24]	[-2.334]	[2.346]		[-6.4]
PT - DE	before	-0.021**	-0.031***	0.013	0.017	-0.009	0.015	0.045	0.007***	0.002	0.006	-0.008	0.005	-0.089**	0.009***	1	-0.063
		[-1.992]	[-2.917]	[1.312]	[0.814]	[-1.554]	[1.113]	[1.134]	[4.507]	[0.148]	[0.288]	[-1.432]	[0.366]	[-2.209]	[6.162]		[-0.65]
	after																-
																	-
PT - UK	before	-0.022***	-0.012	0.013*	-0.007	-0.005	-0.001	-0.009	0.006***	0.004	0.003	-0.012**	0.009	-0.078*	0.01***	1	0.036
		[-2.754]	[-1.071]	[1.742]	[-0.477]	[-1.204]	[-0.105]	[-0.31]	[5.69]	[0.385]	[0.15]	[-2.186]	[0.66]	[-1.911]	[6.376]		[0.41]
	after																-
																	-
PT - GR	before	0.006	0.035**	0.004	-0.031	-0.01*	0.002	-0.033	0.008***	0	0.001	-0.01*	0.01	-0.074*	0.009***	1	-1.034***
		[0.45]	[2.321]	[0.415]	[-1.56]	[-1.899]	[0.131]	[-0.903]	[6.189]	[-0.008]	[0.048]	[-1.773]	[0.753]	[-1.844]	[6.125]		[-15.03]
	after	-0.006***	-0.001	-0.011	0.042	0	-0.004	-0.079*	0.002*	-0.004	-0.036	-0.002	-0.003	-0.078**	0.002**	1	0.136
		[-2.97]	[-0.488]	[-0.647]	[0.524]	[0.052]	[-0.362]	[-1.658]	[1.801]	[-0.298]	[-0.64]	[-0.971]	[-0.334]	[-2.38]	[2.326]		[0.2]
PT - IR	before																-
																	-
	after																-
																	-
PT - IT	before	-0.034***	-0.018	0.023**	0.013	-0.011**	0.018	-0.09**	0.01***	0.006	0.004	-0.012**	0.012	-0.082**	0.01***	1	-0.269***
		[-2.848]	[-1.448]	[2.251]	[0.59]	[-2.045]	[1.346]	[-2.296]	[6.603]	[0.526]	[0.164]	[-2.034]	[0.864]	[-2.045]	[6.401]		[-3.04]
	after	-0.024***	-0.01*	-0.011	-0.035	0.001	0.004	-0.297***	0.002*	0	-0.049	-0.003	-0.002	-0.079**	0.002*	1	-0.498***
		[-3.5]	[-1.787]	[-0.75]	[-0.54]	[0.311]	[0.415]	[-7.677]	[1.93]	[0.03]	[-0.893]	[-1.109]	[-0.293]	[-2.441]	[1.933]		[-2.8]
PT - SP	before																-
																	-
	after	-0.035***	-0.024***	0.003	-0.06	-0.001	0.001	-0.232***	0.002**	0	-0.05	-0.003	-0.002	-0.075**	0.002**	1	-0.294**
																	[-2.38]

This table shows the coefficients estimates of CDS markets co-movement in long-run and short run. The VECM model is defined as Eq 19 and 20. The β matrix describes the long-run relationship between sovereign CDS spreads. The α, speed of adjustment, measure the speed of each market adjusting to long-run equilibrium. If α is significantly negative, the corresponding market would adjust back to the long-run equilibrium, driven by the error correction term ε. When the cointegration relation is rejected for pairs of CDS spreads, the VECM estimation would show as blank. Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

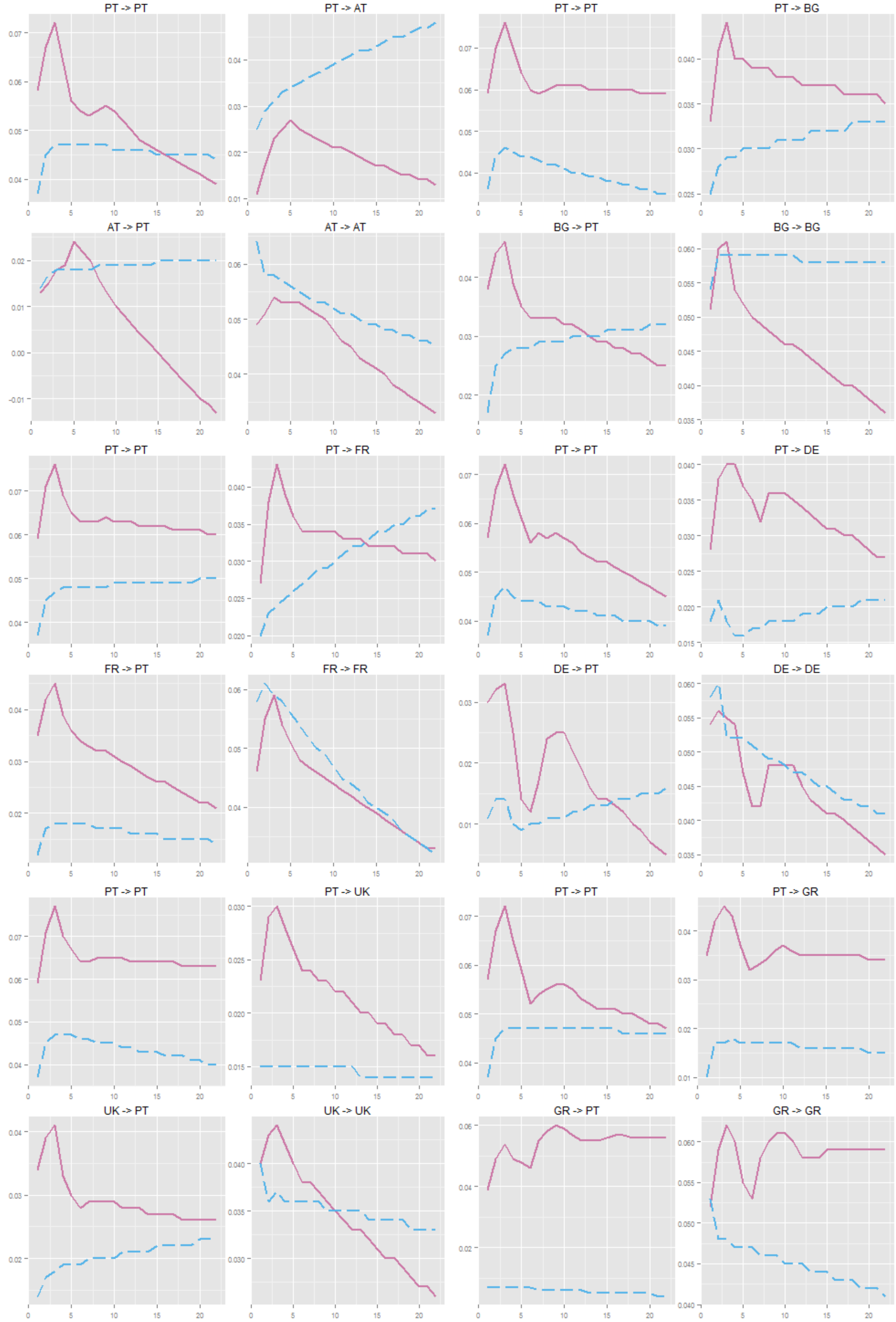
4.6.2.3.2 Impulse response

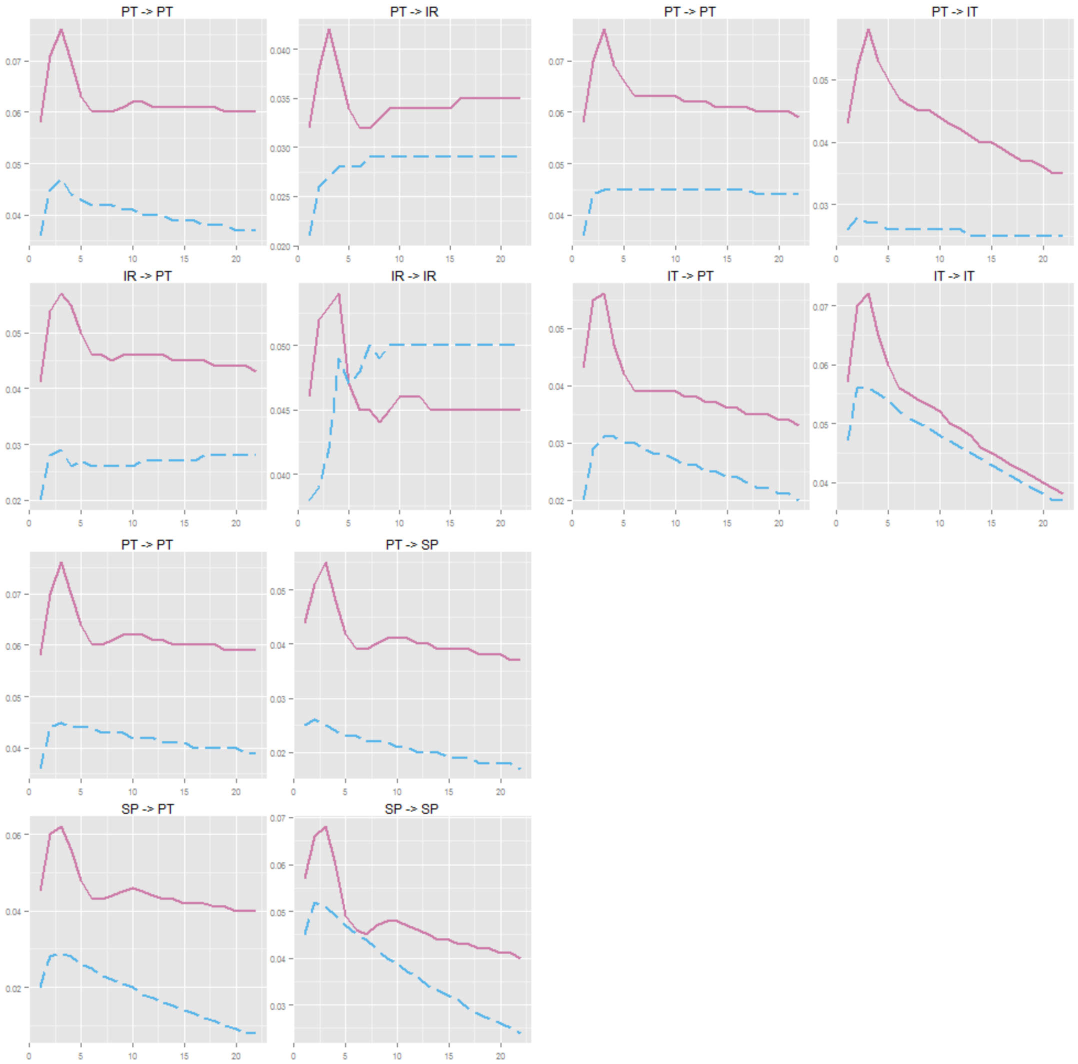
Figure 11 describes the impulse responses analysis for Portugal and other countries, in the pre- and post-bailout periods. Before the bailout, Portugal's responses to shocks in other EU countries follow an interesting pattern. A shock originating from the core countries is found to lead to a temporary shift in the Portugal spreads ($t<5$), while a shock on one of the PIIGS countries has a permanent effect on Portugal's spreads. Moreover, it suggests close interdependency among PIIGS countries before bailout. A permanent reaction is found in most countries facing a Portugal shock, except for the UK. After bailout, a shock from most of EU countries (all the core nations and most of the PIIGS, but not Spain) has a significant and permanent influence on Portugal's spread. Furthermore, the influence from the core countries, AT, BG and DE are stronger compared with the pre-bailout period.

A PT shock was able to cast a significant and long-term influence on most other EU nations before the bailout. However, afterwards, the influences from EU country shock are generally weaker, even though these are stable and permanent responses. Only AT and FR shocks show a greater impact on PT spread than in the pre-bailout period.

In terms of response to a shock from itself, PT is less sensitive to a PT shock after the bailout, in its relations with all other countries. All the core countries have a greater response to an internal shock in the post-intervention period.

Figure 11 GIRF for Portugal bailout





This figure presents the generalized impulse responses for the Portugal bailout. The dynamic between PT and AT, BG, FR, DE, UK, GR, IR, IT and SP are plotted as a group of four, 2×2. e.g., the four graphs on top left panel show the GIRF for Portugal and Austria respectively: PT (impulse variable) -> PT (response variable); PT (impulse var.) -> AT (response var.); AT (impulse var.) -> PT (response var.); AT (impulse var.) -> AT (response var.).

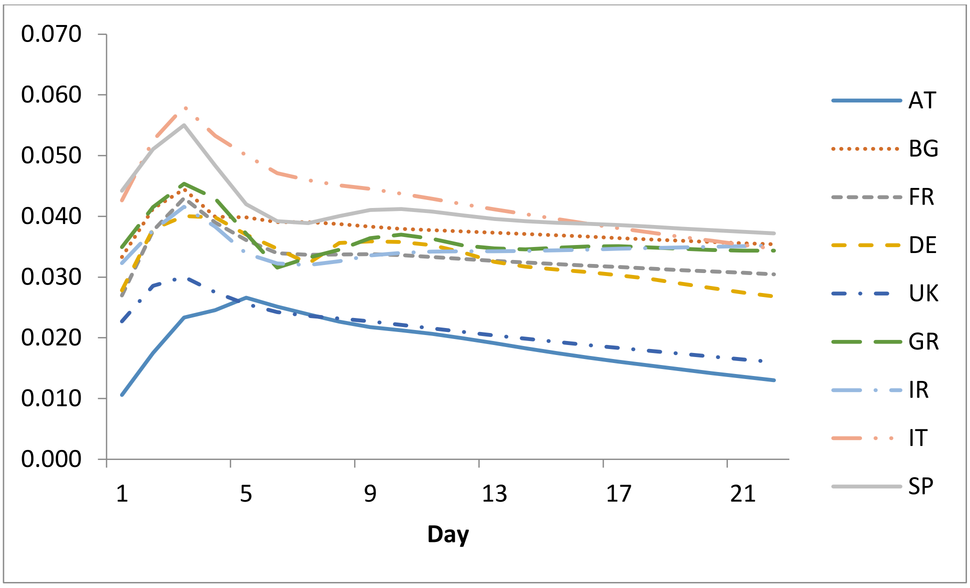
Note: X-axis: number of days after the shock generated from the impulse variable. Y-axis: response to a one standard deviation shock in impulse variable. Red solid lines: impulse responses before bailout. Blue dashed line: impulse responses after bailout plan is activated.

4.6.2.3.3 Cross-country analysis

Figure 12 shows the impulse response of EU countries to a PT shock, before Portugal's bailout. A PT shock could lead to a stable response in other EU countries. The long-term response of PIIGS countries are clustered (led by IT and SP) at around 0.04, while the responses of cores show some gap between each other (the UK and AT are the least affected). This result indicates that investors in the PIIGS countries have similar attitude to news from Portugal, which further supports the inter-connection between PIIGS and the crucial importance of being bailed-out. The responses of the core countries can be ranked highest to lowest: BG, FR, DE, UK and AT. BG, the most "PIIGS" member of the "Core" group, given that it has the highest debt-GDP ratio, had a higher sensitivity to PT shock than the other core countries.

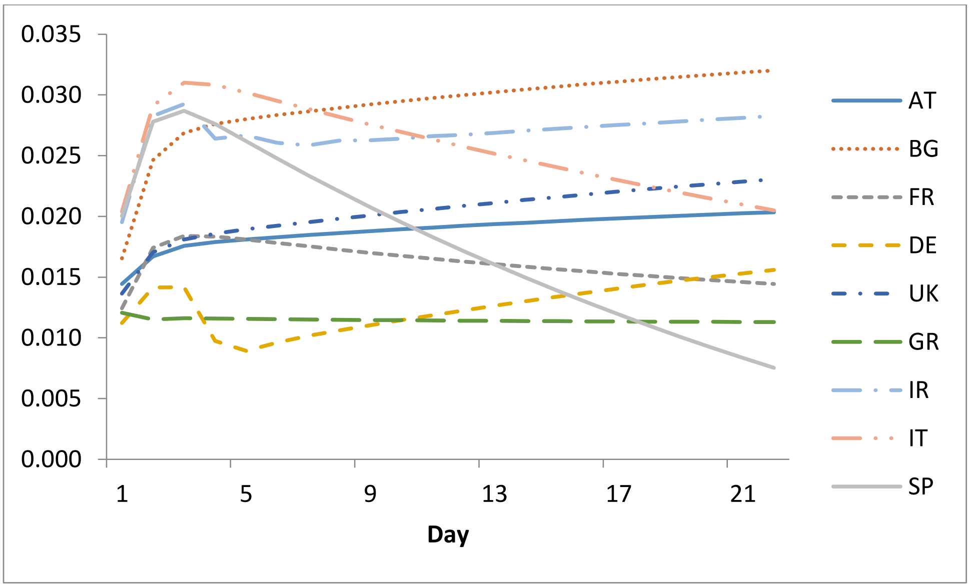
Figure 13 demonstrates the PT response to shock from other EU countries, after its bailout. This figure shows the increasing influence of the core countries on the development of PT spread, led by BG and UK. An upward and constant response of PT is found in the relation with all core countries, while the impact from the PIIGS appears to be much weaker, except for IR and IT. Italy, having the second highest debt-GDP ratio (120%) in the Eurozone in 2010, is the only country among the PIIGS not to receive an official bailout. It is reasonable for investors to believe that the IT spreads contain constantly updated "new" information that is used to affect other countries' CDS spreads. However, it is interesting to find that IR, as a country that previously experienced bailout, still had a significant influence on PT spread, while SP, the only remaining PIIG yet "to be bailed-out", has only a short-term impact on PT and the second least influence over the long run.

Figure 12 EU countries' responses to PT shock, before bailout



This figure depicts the response of EU countries to PT shock, before PT bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while GR, IR, IT and SP are the group of PIIGS (bottom four in legend).

Figure 13 PT response to shock from EU countries, after bailout



This figure depicts the response of PT spread to shock from other EU nations, after PT bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while GR, IR, IT and SP are the group of PIIGS (bottom four in legend).

4.6.2.3.4 Discussion

After the 2008 financial crisis, two Portuguese banks, BNP and BPP, fell into serious difficulty, which forced the Portuguese government to step in and give them a bailout so as to prevent the financial crisis from spreading. Portuguese government bonds faced increased pressure after Moody lowered its rating in 2010. Therefore, to stabilize its public finance, the European Financial Stabilisation Mechanism, the European Financial Stability Facility and the IMF approved a three-year loan of up to €78 billion to the Portuguese government. Through the bailout plan, Portugal's spreads are expected to be highly affected by the core nations that financed the rescue plan. Before bailout, credit risk spillover is seen from PT to most other countries, except for the UK, according to the Granger causality results. In addition, the leading role of PT is highlighted by the cointegration test, as all core nations adjusted back to the long-term equilibrium. Therefore, our H1 is supported in Portugal's bailout.

After the Portugal bailout, risk spillover into the core countries is seen: Austria and France. This is supported by the Granger causality test and the permanent effect of PT shock on AT and FR, which are the two nations most influenced by PT shock across all 9 EU members. These results support our H2, that because of credit risk transfer, the bailed-out country has a stronger explanatory power for the spreads of core nations.

Moreover, shocks to all the core countries, AT, BG, FR, DE and UK, have a permanent and significant effect on Portugal's spreads after the intervention, of which AT, BG and DE shock has increasing effect on PT spread. Nevertheless, Granger causality testing suggests only BG could Granger-cause PT. No similar impact is observed for the other PIIGS countries. Therefore, H3 is partially confirmed.

Considering the reduced level of reaction to its own shock from the GIRF results, Portugal becomes more sensitive to changes in the core countries after bailout, from which it may be concluded that the bailout plan successfully transferred credit risk from Portugal to the core countries.

As for H4, before bailout, a PT shock led to a higher long-term response for PIIGS countries, clustered at 0.04 bp, and lower responses in core countries. This underlines that investors in the PIIGS countries share similar attitudes to PT information, and the crucial importance of the factor 'might have to be bailed-out', as Italy (which actually did not prove to need a bailout, though there was the prospect of this at the time) and Spain (which was the next to receive a bailout) are the most sensitive to PT shock. After the bailout, the core countries had a greater influence on the PT spread, indicating enhanced influence of cores over the development of CDS spreads in the bailed-out country.

To sum up, our results support H1, as we found strong and permanent responses to shocks in Portugal. After the bailout plan was implemented, causality and cointegration tests and the GIRF results support spillover from Portugal to two core countries over the long term, Austria and France, which supports our H2. In addition, according to GIRF, with a reduced level of sensitivity to its own shock, Portugal became more sensitive to shifts in the core countries after its bailout, which supports our H3. The clustered response of PIIGS countries before intervention and the strong influence from the core are in line with the country-specific characteristic: as a country's spread becomes more informative, it has a higher impact on the bailed-out country.

4.6.2.4 Spain's bailout

As the last country asking for bailout, on 9 June 2012, Spain was granted €100 bn in order to help its failing banks (Spain having partly nationalized Bankia SA in May). Bilateral relationships are studied for 8 EU countries (Greece exited the debt market after it defaulted), in two sub-periods: pre-bailout and post-bailout. The Granger causality test results are presented in Table 22, cointegration test results are shown in Table 46, with VECM and IRF in Table 23 and Figure 14.

4.6.2.4.1 Granger causality and cointegration

The Granger causality test results suggest that, changes in SP could Granger-cause all EU countries, while AT, FR, DE and PT could Granger-cause SP. This indicates both that the spillover is directed from the rescued country to others, and that there was a significant effect on PT spread from the core European countries.

Cointegration analysis reveals a stable long-run relation between SP and all other countries with the exceptions of IR and IT. For example, $\beta_{FR} = -0.916$ bp shows that a 1 bp decrease in SP translates into a 0.916 bp drop in FR spread over long-run.

The α coefficients in Table 23 suggest that all of the core countries adjust to long-run equilibrium, while PT is less active in adjustment at the 5% level of significance. In the relation with BG and FR, the SP results do not participate in the error correction mechanism for these nations. AT, DE, UK and PT are the nations that SP actively involves in the error correction. Therefore, we conclude that spillover originates from Spain and influences most other countries, as shown by Granger causality testing.

Comparing the magnitude of α coefficients, we find that $|\alpha_{BG}|$and $|\alpha_{FR}|$ are larger than their corresponding$|\alpha_{SP}|$, although there is no significant difference in the relation with others. The causality is then suggested to be from SP to the cores, before bailout.

After the bailout plan is implemented, the Granger causality relation between SP and other countries shows that SP could Granger-cause all other countries (with the exception of IT), and only be Granger-caused by AT.

Of the five core countries, only AT, BG and FR were still in a long-term relation with PT after the bailout. Compared with the pre-bailout period, the decreases in the β coefficients for BG and FR suggest their greater influence on SP over the long run, from $\beta_{BG} = -1.024$ bp and $\beta_{FR} = -0.912$ bp to $\beta_{BG} = -1.46$ bp and $\beta_{FR} = -1.072$ bp, respectively. The insignificant α coefficients of SP suggest that Spain provides the stochastic trend in the error correction with all these cointegrated countries. On the other hand, all the core countries adjust to close the gap. These results emphasize the lead role of Spain's spreads, after bailout. Compared with the pre-bailout period, the speed of adjustment is greatly increased for BG and FR, at -0.072 and -0.112. France's CDS spreads are the most active among all the cointegrated nations. It also supports our H2, of an increased influence from the bailed-out countries to the cores.

Table 22 Granger causality test for Spain's bailout

Variables	Period	PIIG not GC others		others not GC PIIG	
		test	Pr()	test	Pr()
SP - AT	before	**12.416**	**0.000**	**3.253**	**0.006**
	after	**3.554**	**0.001**	**4.601**	**0**
SP - BG	before	**4.145**	**0.000**	1.188	0.31
	after	**4.422**	**0.013**	2.236	0.11
SP - FR	before	**8.111**	**0.000**	**2.13**	**0.048**
	after	**12.044**	**0.000**	0.091	0.913
SP - DE	before	**11.627**	**0.000**	**6.099**	**0**
	after	**2.753**	**0.067**	0.445	0.642
SP - UK	before	**5.470**	**0.000**	1.449	0.172
	after	**3.058**	**0.012**	**1.936**	**0.091**
SP - IR	before	**5.673**	**0.000**	1.267	0.276
	after	**6.894**	**0.000**	0.425	0.791
SP - IT	before	**2.029**	**0.073**	0.395	0.852
	after	0.275	0.760	0.24	0.787
SP - PT	before	**6.448**	**0.000**	**3.556**	**0.007**
	after	**9.566**	**0.000**	1.432	0.242

The Granger causality test provides direction of information flows, when the lag is chosen by AIC. Its F-test results are summarized. The test equation is $y_t = \alpha + \sum_{i=1}^{5} b_i y_{t-i} + \sum_{j=1}^{5} c_j x_{t-j}$, the null hypothesis is that x does not Granger cause y, $c_j = 0$ for all j. If the statistic exceeds the 10% critical value (indicated by bold type), the null hypothesis of absence of Granger causality is rejected.

Table 23 VECM for Spain's bailout

Variables	Period	α_{others}	α_{PIIGS}	α_{11}	α_{12}	α_{13}	α_{14}	α_{15}	α_{16}	α_{21}	α_{22}	α_{23}	α_{24}	α_{25}	α_{26}	β_{others}	β_{PIIG}
	before	-0.014**	-0.016***	0	-0.022	-0.001	-0.002	-0.06*	0.004***	0.006	-0.032	-0.002	-0.001	-0.124***	0.006***	1	-0.197
SP - AT		[-2.178]	[-2.627]	[0.005]	[-0.787]	[-0.347]	[-0.17]	[-1.777]	[3.688]	[0.599]	[-1.268]	[-0.769]	[-0.175]	[-4.017]	[5.803]		[-1.14]
	after	-0.011***	-0.005**	-0.002	0.148*	0.007	-0.017	-0.068	0	0.002	0.113*	-0.002	-0.016	-0.348***	0.001	1	0.003
		[-4.064]	[-2.357]	[-0.113]	[1.792]	[1.196]	[-0.88]	[-0.88]	[-0.086]	[0.109]	[1.684]	[-0.485]	[-0.967]	[-5.542]	[0.586]		[0]
	before	-0.034***	-0.018	0.004	-0.014	-0.006**	0.011	-0.113***	0.005***	0.007	-0.034	-0.004	0.003	-0.129***	0.006***	1	-1.024***
SP - BG		[-3.104]	[-1.481]	[0.433]	[-0.611]	[-2.244]	[1.46]	[-3.956]	[5.681]	[0.7]	[-1.312]	[-1.247]	[0.34]	[-4.12]	[5.394]		[-13.85]
	after	-0.072***	-0.013	0.004	-0.009	0.003	-0.014	-0.342***	0.002	-0.007	0.16***	-0.001	-0.014	-0.395***	0.002	1	-1.46***
		[-3.533]	[-0.984]	[0.221]	[-0.097]	[0.399]	[-0.533]	[-3.402]	[0.639]	[-0.567]	[2.656]	[-0.136]	[-0.862]	[-6.292]	[0.873]		[-8.25]
	before	-0.036***	-0.016	0.008	-0.014	-0.002	0	-0.103***	0.006***	0.006	-0.033	-0.003	0.002	-0.124***	0.005***	1	-0.912***
SP - FR		[-3.287]	[-1.418]	[0.904]	[-0.584]	[-0.737]	[0.051]	[-3.534]	[6.527]	[0.64]	[-1.276]	[-0.982]	[0.196]	[-3.961]	[5.358]		[-11.59]
	after	-0.112***	-0.015	-0.01	0.103	0.006	-0.022	-0.249***	-0.004	-0.003	0.124**	-0.001	-0.012	-0.384***	0.002	1	-1.072***
		[-3.435]	[-0.627]	[-0.596]	[1.229]	[0.959]	[-0.977]	[-2.798]	[-1.046]	[-0.231]	[2.062]	[-0.287]	[-0.743]	[-6.006]	[0.699]		[-9.81]
	before	-0.023***	-0.022***	-0.002	0.004	-0.006*	0.017*	-0.052	0.006***	0.005	-0.033	-0.003	0	-0.113***	0.006***	1	-0.385***
SP - DE		[-2.778]	[-2.842]	[-0.21]	[0.155]	[-1.785]	[1.915]	[-1.583]	[5.44]	[0.506]	[-1.294]	[-1.046]	[-0.039]	[-3.646]	[5.562]		[-3.17]
	after																-
																	-
	before	-0.018**	-0.021**	0.001	-0.019	0	-0.002	-0.039*	0.004***	0.006	-0.033	-0.004	0.002	-0.126***	0.006***	1	0.021
SP - UK		[-2.472]	[-2.141]	[0.128]	[-1.005]	[-0.17]	[-0.298]	[-1.662]	[5.752]	[0.662]	[-1.283]	[-1.368]	[0.231]	[-4.013]	[5.358]		[0.17]
	after																-
																	-
	before																-
SP - IR																	-
	after																-
																	-
	before																-
SP - IT																	-
	after	-0.094	0.013	0.006	0.076	0.002	-0.021	-0.434***	0.001	-0.001	0.121**	-0.001	-0.014	-0.386***	0.002	1	-1.055***
		[-1.323]	[0.184]	[0.542]	[1.284]	[0.513]	[-1.317]	[-6.883]	[0.381]	[-0.102]	[1.987]	[-0.269]	[-0.844]	[-5.99]	[0.729]		[-27.8]
	before	0.005	0.016***	0.005	-0.037	-0.008***	0.005	-0.066**	0.005***	0.006	-0.039	-0.003	0.003	-0.121***	0.006***	1	-1.973***
SP - PT		[0.982]	[2.735]	[0.541]	[-1.472]	[-2.851]	[0.609]	[-2.207]	[5.577]	[0.661]	[-1.536]	[-1.087]	[0.357]	[-3.918]	[5.55]		[-10.78]
	after	0.02	0.061***	0.003	0.038	0	0.004	-0.165***	0.001	-0.002	0.123**	0	-0.018	-0.388***	0.002	1	-0.923***
		[1.326]	[3.107]	[0.353]	[0.847]	[-0.04]	[0.326]	[-3.471]	[0.342]	[-0.168]	[2.108]	[-0.075]	[-1.117]	[-6.255]	[0.781]		[-6.28]

This table shows the coefficients estimates of CDS markets co-movement in the long run and short run. The VECM model is defined in Eq 19 and 20. The β matrix describes the long-run relationship between sovereign CDS spreads. The α, speed of adjustment, measure the speed of each market adjusting to long-run equilibrium. If α is significantly negative, the corresponding market would adjust back to the long-run equilibrium, driven by the error correction term ε. When the cointegration relation is rejected for pairs of CDS spreads, the VECM estimation would show as blank. Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

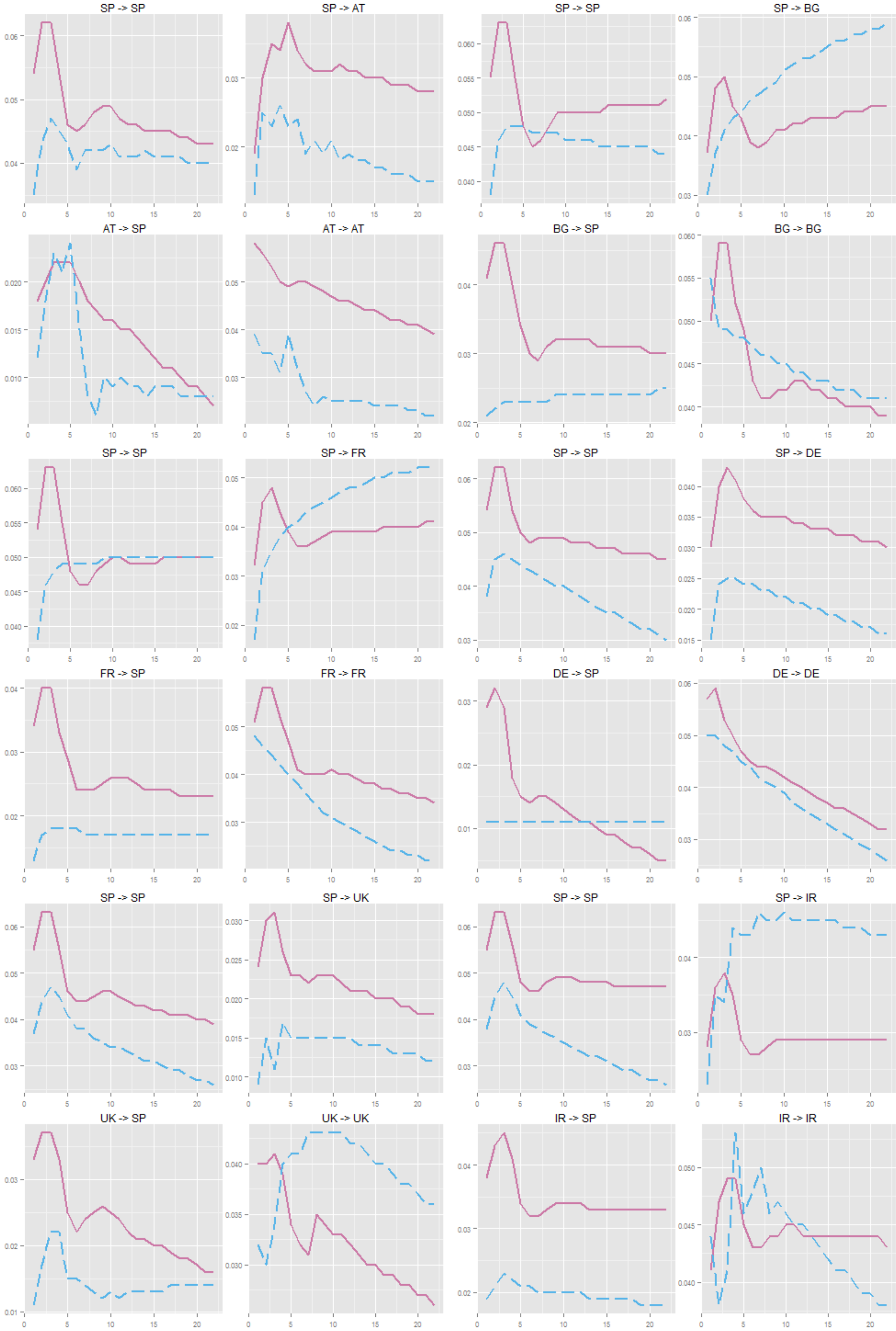
4.6.2.4.2 Impulse response

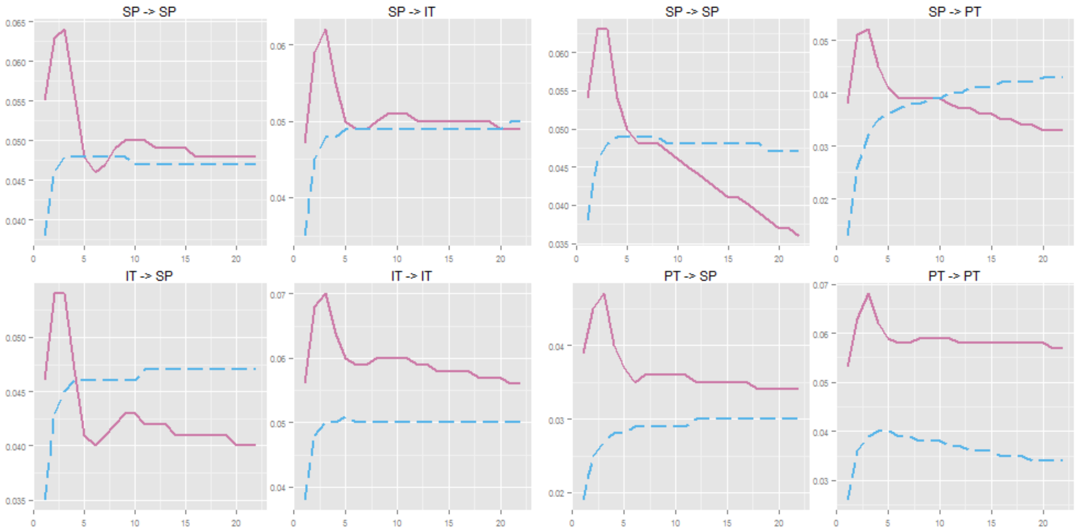
The results of IRF are plotted in Figure 14, as a panel of 2×2 graphs. The response of Spain to a shock in other EU countries before the bailout shows a similar trend: shock from any EU country only temporally affects Spanish CDS spread, which decreases rapidly after day 3. However, after the bailout, the influences on SP become stable and permanent, although some of them appear weaker than before. German and Italian shocks have a stronger impact on Spain spread in the post-bailout period than in the pre-bailout period, while Austrian and UKs shocks have the same level of influence as in the pre-bailout period, at day 22.

The responses to a Spanish shock in the pre-bailout period of eight countries are both stable and permanent, but not for the UK. A similar but stronger and increasing response to SP shock is found for the post-bailout period for BG, FR, IR, IT and PT. It can be concluded that Spain had a higher impact on other members in the EU, especially the PIIGS, after bailout.

In addition, shocks originating from Spain have a weaker influence on Spanish spreads after bailout, in the relation with all other nations. The core countries' reaction to an internal shock follows the downward pattern, which is weaker in the latter period.

Figure 14 GIRF for Spain's bailout





This figure presents the generalized impulse responses for Spain's bailout. The dynamics between SP and AT, BG, FR, DE, UK, IR, IT and PT are plotted as a group of four, 2×2[29]. e.g., the four graphs on top left panel show the GIRF for Spain and Austria respectively: SP (impulse variable) -> SP (response variable); SP (impulse var.) -> AT (response var.); AT (impulse var.) -> SP (response var.); AT (impulse var.) -> AT (response var.).

Note: X-axis: number of days after the shock generated from the impulse variable. Y-axis: response to a one standard deviation shock in impulse variable. Red solid lines: impulse responses before bailout. Blue dashed line: impulse responses after bailout plan activated.

4.6.2.4.3 Cross-country analysis

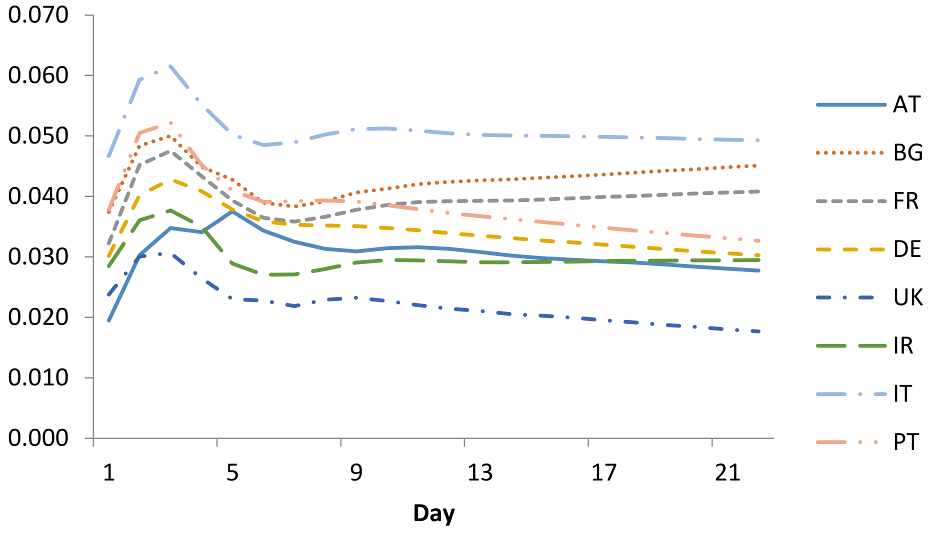
Figure 15 shows the impulse response of EU countries to Spanish shock over the long run (22 days), before Spain's bailout. The strong impact of SP shock appears to be consistent for both groups of countries. The most heavily influenced is IT spread, over 0.05 bp, followed by BG and FR. A pattern may be found in the results: the nations with more "uncertainty" are more influenced by SP shock, like IT, BG and FR. They share the same feature: they had not experienced any bailout, but did have high debt-GDP and deficit-GDP ratios. On the other hand, the least affected countries, the

[29] Greece had already defaulted on its sovereign debt when Spain asked for a bailout from the EU and IMF. Therefore, the relationship between Spain and Greece is not examined.

UK, AT and DE, are more optimistic on their fiscal outlook. Furthermore, because of their previous bailout, IR and PT were not much affected by SP shock.

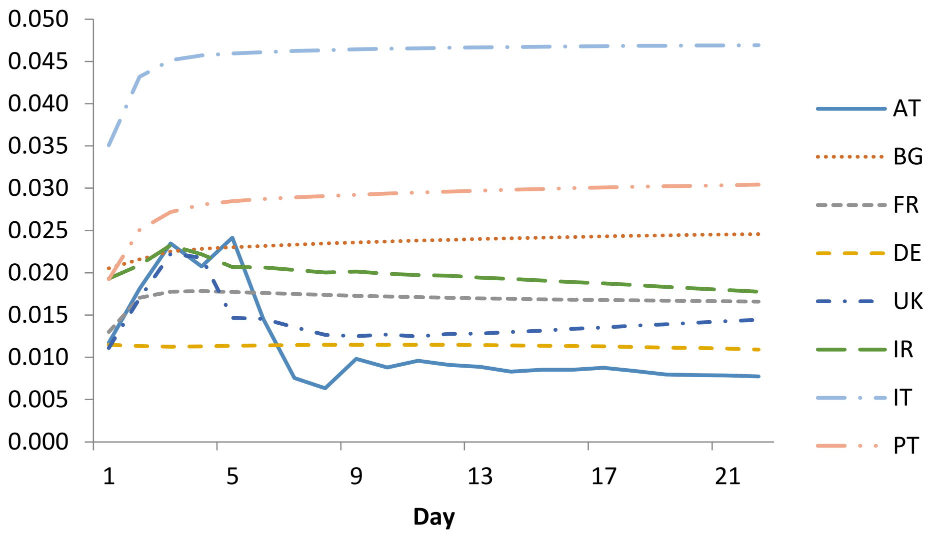
Figure 16 depicts the SP response to shock from other EU members, after SP bailout. The response of SP is permanent and stable for shock from all other nations. SP spread was the most sensitive to IT shock, which led others by over 0.015 bp. The concern about Italy's domestic economy with high national debt and future spillover from other PIIGS means that IT spreads contain important information for other countries. In terms of the magnitude of response, the core nations have limited influence compared with the PIIGS. The responses of the core countries can be ranked (highest to lowest): BG, FR, UK, DE and AT. Also, although two core countries, BG and FR, have a greater influence on SP spread after bailout, the dominant effect on SP depends on the information contained in the spread of a country, which explains the close connection between the PIIGS.

Figure 15 Response of EU countries spreads to Spain shock, before bailout



This figure depicts the response of EU countries to SP shock, before SP bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while IR, IT and PT are the group of PIIGS (bottom three in legend).

Figure 16 Spain response to shock from other EU nations, after bailout



This figure depicts the response of SP spreads to shock from other EU nations, after SP bailout, using the GIRF estimation results (for 22 days). The core nations include AT, BG, FR, DE and UK (top five in legend), while IR, IT and PT are the group of PIIGS (bottom three in legend).

4.6.2.4.4 Discussion

Claiming a bank rescue plan rather than sovereign rescue package during the sovereign debt crisis, Spain asked for €100 bn to help its failing nationalized banks: Bankia, Catalunya Banc, NCG Banco and Banco de Valencia. As the fifth largest economy in the EU, Spain had the lowest debt level among the other 10 EU member states studies here (53.9% in 2010), from 2007 to 2012. However, the government spent a large amount of money to bail out banks after a housing bubble burst. Spain maintained a high deficit-GDP ratio since 2009 (around 10%) and the highest unemployment rate in the EU, of over 20% in 2011. The difficulty in bond markets in June 2012 led to the €100 bn banking sector support package.

Spain should be less affected by other sovereign states but have a large influence on others, considering its importance in the EU economy and relatively stable sovereign debt compared with the other PIIGS. The argument is supported by the Granger causality test and cointegration test results, where we find only AT, FR, DE and PT could Granger-cause the Spanish spreads, while the latter were able to Granger cause most of the other countries. A Spanish shock had a permanent effect on other countries before the bailout, which is in line with our H1.

After bailout, the Granger causality test underlines the importance of SP spread in determining others, as SP Granger-caused all core nations, which backs our H2. Additionally, cointegration analysis suggests that SP spread does not join the error correction but provides the stochastic trend. Furthermore, IRF results imply that BG, FR, IR, IT and PT are more sensitive to changes in SP after its bailout. The finding is in agreement with the hypothesis that Spain, as the fifth largest economy in the EU, has a large influence on others when these EU nations are more exposed to Spanish risk through their provision of funds for the bailout.

Financial aid from the core countries serves as credit guarantee for Spain led to Spain's higher reliance on the cores. Although AT, DE, UK and IT still had a significant influence on SP after the bailout, other countries' spreads show much weaker impacts on SP, as the Granger causality test suggests by finding only AT could Granger-cause SP. Furthermore, in the long-term relation, SP fails to join the error correction in all cases. It is consistent with our assumption that SP would be less affected by others, due to the nature of the bailout. Therefore, Hypothesis 3 is supported only in the cases of Austria and Germany, which are the influential forces in the EU.

Comparing the responses across countries, we find support for a difference in reaction being caused by country-specific characteristics (H4). Before intervention, countries with more information (no bailout, high debt and deficit) are more influenced by SP shock, while least affected countries were those with a better fiscal outlook. A similar pattern is found in the post-bailout period.

To sum up, our results support H1, as Granger causality and cointegration tests and IRF suggest that Spain led and then spilled over into other countries before its bailout. After announcement of the aid package, the lead role of Spain was enhanced for most countries, supporting H2. According to IRF, although the impact of other nations was shown to be stable, most of their influences were weaker than in pre-bailout periods. H3 is supported only in the relations between Spain and Austria and Germany, the most active forces in these bailouts. However, comparing across countries, AT and DE are not the most important factors in determining Spain's spreads, as other PIIGS and BG shocks can trigger larger responses. In the cross-country analysis, the fiscally healthy and the bailed-out nations are less connected with Spain's spread. In addition, the non-bailout PIIGS were closely linked to SP spread. Thus, H4 is confirmed by the importance of country-specific characteristics. The influence of a country (how much a country affects others) depends on its "information", while its sensitivity to an external impact (how much a country is affected by others) depends on its "fiscal situation".

4.7 Conclusions and implications

Sovereign credit rating, serving as an indicator of a country's credit risk, has been a hotly debated topic in both industry and academia, particularly since the start of the Eurozone sovereign debt crisis. Academic studies from the 1990s onwards suggest that it has significant influence on the bond, stock and CDS markets. We study the dynamic between daily sovereign credit rating and outlook and CDS spreads for 37 international markets from November 2004 to June 2012, and the spillover effect between these markets. We apply a VECM model and Granger causality test in order to estimate bi-directional links between credit ratings and sovereign CDS spreads. Under a panel regression framework, we focus on spillover of sovereign rating information to CDS spreads across borders over periods of crisis (December 2007–June 2009, August 2010–June 2012) and pre-crisis (November 2004–December 2007, June 2009–August 2011).

First, our results show the bilateral links for daily CDS spreads in international markets and sovereign credit rating/outlook. There is a significant response of government CDS spreads to both rating and outlook, with a long-run equilibrium relationship between sovereign CDS spreads and rating/outlook for the majority of countries. Credit ratings and outlooks lead sovereign CDS spreads in most cases. Past rating and outlook revision may help to anticipate changes in sovereign CDS spreads but the results of the Granger causality tests suggest a mixed causality relation.

Second, we find negative international spillover effects of outlook changes on CDS markets, but no similar influence from rating changes. These results imply that outlook improvement not only narrows the CDS spreads of local countries but also affects those in other markets. Moreover, credit quality of the home countries does not have much influence on such spillover, while its ‘outlook’ shows significance at the 10% level. The results further suggest spillover is a regional effect rather than a global effect. Countries within the same region share more linkages through bilateral and third-party trading, commonalities among lenders, political connections and other sources (Kaminsky and Reinhart, 2003), making sense of spillover being limited to the same region. However, the US market is found to have a significant global influence.

Finally, during times of crisis, sovereign CDS spreads become more sensitive to external factors: regional outlook changes and the US market. These external spillover factors had a much weaker influence in the pre-crisis period. This is in line with the findings of Fender et al. (2012), who suggest that, in the times of turmoil, international investors are more sensitive to recent developments in the global environment. Generally in the spillover estimation, credit outlook had more persistent effect on CDS spreads than credit rating, suggesting that outlook changes have a greater influence on changes in CDS spreads.

Overall, we find that sovereign CDS markets react to and are led by credit rating and outlook. Over the short term, rating and outlook changes in countries within the same region can strongly influence CDS spreads. This spillover effect is especially strong during periods of crisis. The large US market has a unique, universal impact on other markets.

As for the Eurozone debt crisis, a series of financial supporting measures was introduced by the EU and IMF in order to rescue troubled countries from default. These interventions changed the interaction between the credit risks of the EU members. This study sought to detect bilateral linkages (spillover) in the sovereign credit markets and to capture the presence of any contagion effect by focusing on parallel movements between markets (sovereign CDS and credit rating and the CDS spreads of different countries) in the wake of the recent crisis, and the role of policy intervention in the changes. Four hypotheses are proposed for the study. First, before bailout, changes in the credit risk of bailed-out countries affect the credit risk of core

European countries. Second, after the bailout programmes were implemented, the credit risk changes for bailed-out nations have even more influence on core countries than before. Third, after a bailout, a country's spreads are more sensitive to changes in core countries' credit risk. Finally, comparing the different interactions across countries, we propose that these differences depend on country-specific characteristics, like fundamentals (debt and deficit level) and how informative its spreads are. The vulnerability of a country to external shock depends on its "fiscal situation". The influence of a country's CDS spread depends on its "information".

For the first hypothesis, before intervention, the spreads of bailed-out countries have strong influence on core European countries. This argument is supported in the case of all aid packages: the bailout of Greece 1st, Ireland, Portugal and Spain. We find that the credit risk spillover channel is from PIIGS to the cores before intervention. In this period, the development of the Greek spread contains crucial information for the spread of other EU nations: the fear of contagion and expectation of future financial aid.

Since the financing plan makes the core countries more exposed to the credit risk of the bailed-out country, changes in spreads for the PIIGS are able to trigger a larger shift in core countries (H2), as in the case of Ireland's, Portugal's and Spain's bailout. Nevertheless, not all core countries are more sensitive to a PIIGS after its bailout: this was the case for AT and DE in Ireland's bailout, for AT and FR in Portugal's bailout, and for BG and FR in Spain's bailout. These strongly affected states (Austria, Belgium, France and Germany) are all Eurozone countries, while the UK was less affected. Moreover, the influences of bailout countries differ across cases. Spain's spread shows a significant impact on other PIIGS countries, while Greece, Ireland

and Portugal affect only core countries. The strong effect of a Spanish shock relates to the size of its economy and features of its bailout. This heterogeneity is related to our Hypothesis 4.

As for our third hypothesis, we conclude that the core countries gain more influence on the spreads of bailed-out countries after the intervention for every bailout, especially Austria and Germany, according to IRF. Since the core countries contributed to the funding of the bailouts, and served as credit guarantees for the PIIGS, the bailed-out countries had a greater higher reliance on core countries, which in turn could lead to increased sensitivity of a core country to its own debt crisis if credit issues emerge.

Finally, the spillover of credit risk is consistent across countries and rescue plans after intervention. The links between the bailed-out country and others follows the same pattern, for each bailout. The performance depends on the country-specific characteristic at that time, rather than the group that the country belongs to (PIIGS or core). The influence of a country (how much a country affects others) depends on its "information": the more informative its spread is, the more influence it has. Sensitivity to external impact (how much a country is affected by others) is related to its "fiscal situation": the stronger its fiscal outlook is, the less it is controlled by external shocks.

Thus, this study is able to provide insights for both international investors and policy makers. International investors are worried about the increasing links in asset prices across national boundaries and asset classes. If cross-country and cross-market correlation changes during periods of crisis, portfolio diversification could fail to deliver safety. In these circumstances, diversification strategies for portfolio management would be unable to diversify risk, leaving the portfolio exposed to international shocks. Our results confirm their worries regarding international integration. Nevertheless, our study also suggests that the contagion is regional rather than global. During periods of crisis, further portfolio diversification across international markets could help limit potential credit risk spillover. On the other hand, for speculators, it could create a profit margin in the co-movement if they understand the direction and channels of information transmission. For arbitragers, finding the difference and lead-lag relation between credit derivate markets is profitable.

For policy makers, at the country level, of the two factors affecting contagion, the more crucial is the national fiscal situation. To reduce likelihood of financial contagion, it would be necessary to reduce the fiscal and current account deficit, enhance the quality of the financial sector, and improve the exchange rate (with non-EU currencies). It should also be noted that countries in financial distress are highly sensitive to any shock from the bailed-out countries, as shown in the cross-country IRF analysis. Without reducing the financial stresses, either by improve fundamentals or through rescue funds, it would not be possible to keep the sovereign credit market stable and solid.

At the EU policy level, the euro was introduced to provide a strong currency across financial markets and avoid devaluations. The stability pact forces each government to remain within the deficit limit, at 6%, and debt limit, at 60%. But there is no supranational government to control tax, spending and transfer between poor and rich members. Although different countries fell into crisis for different reasons, excessive credit creation was a common factor that needs to be taken account of by regulators and policy makers. The crisis resolution mechanism (the ESM) provides a precious lesson for the EU, and may serve as evidence of the need for a Eurobond, as that might to solve the debt issue forever.

The ECB faces constitutional and political obstacles, and is unable to act like the Bank of England, for instance, which has used QE to allow the purchase of government debt. The ECB has nevertheless done a considerable part in avoiding an even worse crisis, by adopting a series of “unconventional measures”. Setting up a permanent firewall to protect its members from future crisis should be on its task list.

CHAPTER 5

Dynamic correlation between variances in sovereign CDS market during the Eurozone debt crisis

5.1 Introduction

Modelling volatility in financial time series has attracted much attention ever since the introduction of Autoregressive Conditional Heteroscedasticity (ARCH) model by Engle (1982). A large body of literature has been devoted to univariate models, but modelling co-movements of financial volatility is of great practical importance. The instability observed on sovereign CDS spreads of one country is in part due to volatility in another market (volatility spillover), especially surrounding policy intervention date. Reliable estimates of this correlation between financial instruments have been the motivation for both academics and practitioners. Indeed, accurate knowledge of such correlations is critical for many common tasks in financial management. Hedging require estimation of correlations between assets. If the correlations and volatilities change over time, then the hedging strategies will be ineffective and require adjustment to account for the most recent information and changes. Both asset allocation and risk management rely heavily on correlation and covariances. Construction of an optimal portfolio requires a forecast of the correlation of the returns. Similarly, the calculation of the standard deviation of portfolio requires a covariance matrix of all the assets in the portfolio. Furthermore, for a better understanding of the influence of financial policy interventions on market correlations, a study of the nature of such correlations over time is also necessary.

The problem presented by the financial crisis is that the correlation of asset returns, linked by fundamentals, appears to change, across both national boundaries and asset classes (Bollerslev et al., 1988). Andersen et al. (2001) emphasize that correlations increase during periods of high volatility, which crisis periods generally are. Forbes and Rigobon (2002) focus on cross-market correlation coefficients and show that these estimations are biased and inaccurate because of heteroscedasticity. According to their results, higher co-movements in different markets could be caused by increased market volatility. This questions the usual implicit assumption of constant correlation/covariance and calls for econometric approaches to capture the evolution of correlations over time.

To overcome the limitations of conditional variance and heteroscedasticity in previous studies, new models have been developed to control for the phenomenon of time-varying volatility. Based on the multivariate constant correlation generalized autoregressive conditional heteroscedasticity (GARCH) model of Bollerslev (1990), Beine (2004) applies the VEC model of Bollerslev et al. (1988) to look at the impact of central bank intervention on the variances and covariances between yen-dollar and euro-dollar exchange rates. He suggests that increases in the covariance are associated with concerted interventions. In order to investigate the causality of a volatility spillover between the US dollar–Deutschemark and the US dollar–Japanese yen exchange rates, a test statistic built on the results from GARCH estimations was calculated by Hong (2001).

As one extension of the multivariate constant correlation GARCH models, the Dynamic Conditional Correlation (DCC) model is frequently used by researchers for measuring time-varying conditional correlations. It is able to address the heteroscedasticity problem without dividing the whole sample period into sub-periods. Also, the model is able to trace the time-varying correlation coefficients for groups of markets. Chiang et al. (2007) found an increase in correlation and continued high covariance for the Asian crisis in 1997 using a DCC model. More recently, Missio and Watzka (2011) focused on bond market links during the sovereign debt crisis using the DCC approach. They explain why the Engle (2002) model, among other multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) models, is suitable for DCC estimates. The model can capture the dynamics of both the variances and the correlations. Therefore, the estimation method allows for a correction of heteroscedasticity, and, in addition, no exogenous sub-sample assumptions have to be made.

The present study investigates the correlation of variances between 9 major European Monetary Union (EMU) countries' credit default swap (CDS) markets during the sovereign debt crisis, and hence examines the impacts of policy interventions on these markets, using the DCC-GARCH model. Specifically, the main purpose is to assess to what extent the bailout plans influenced the dynamics of correlation. To the best of our knowledge, such a study examining dynamic correlation between variances of sovereign CDS spreads in the context of the Eurozone debt crisis has not been reported. This study sought to reconcile the aforementioned two streams of literature: the econometric approaches estimating the time-varying correlation between markets, and the empirical analysis of the impact of policy intervention.

Understanding the link between financial intervention and cross-country correlation is valuable for both portfolio optimization and forecasting.

The main findings of this study are that correlations between CDS spread variances are dynamic and time-varying for all the sample countries. There was a significant pattern for all the bilateral relations. Most of the policy interventions led to a significant increase in pairwise correlations. A temporary reaction, with a subsequent reversion to the normal range, is suggested to be an intervention-caused contagion effect. Comparing across countries, correlations with Austria and Germany were less volatile and showed a weaker reaction to these interventions. One interpretation of this pattern is that there was "two-way feedback" between the healthy country and the bailed-out country, as proposed by Acharya et al. (2011), in the form of public-to-public risk transfer. The increased debt and deficit partly result from assisting other troubled nations. Through policy interventions, any deterioration in the sovereign creditworthiness of the healthy countries can transmit back to the bailed-out countries.

To assess the impact of policy intervention, our empirical analysis controls for the external regressors, including implied volatility of S&P 500 index options (VIX) and credit rating and outlook. The estimation result suggests that credit rating and outlook and VIX do not show much impact on the dynamic conditional correlations between the variances of EMU countries, while announcements of policy intervention have a significant and consistent impact on pairwise cross-market correlations. This finding suggests that policy interventions play a direct and significant role in shaping the structure of dynamic correlations in EMU markets.

5.2 Data

We use daily sovereign CDS spread for 9 EMU countries in Dataset 2: Austria (AT), Belgium (BG), France (FR), Germany (DE), Greece (GR), Ireland (IR), Italy (IT), Portugal (PT), and Spain (SP). Our sample time span starts from 28 April 2009 (shortly after the bank bailout programme was implemented but before Greece announced its 12.5% deficit) and ends at 17 February 2013. We also include the implied volatility of S&P 500 index options, VIX. This serves as a proxy for global financial and economic influence and captures international investors' risk aversion, as it was shown to be a constant and significant source of international spillover in the previous chapter. The sovereign credit rating and outlook changes for the 9 countries in the sample are also included to examine their impact on the dynamic correlations.

The Ljung-Box test results, presented in Table 24, show that most of the countries have autocorrelation at lag 1, and most of them remain autocorrelated with more lags. The ARCH-LM test results, shown in Table 25, reveal that all series exhibit conditional heteroscedasticity, and justify application of the GARCH model.

Table 24 Ljung-Box test for CDS spread changes

Lag	1	2	3	4
Austria	0.578	0.814	0.435	0.528
Belgium	0.000***	0.000***	0.000***	0.000***
France	0.000***	0.000***	0.000***	0.000***
Germany	0.044**	0.008***	0.021**	0.022**
Greece	0.168	0.170	0.041**	0.043**
Ireland	0.003***	0.005***	0.003***	0.000***
Italy	0.000***	0.000***	0.000***	0.000***
Portugal	0.000***	0.000***	0.000***	0.000***
Spain	0.000***	0.000***	0.000***	0. 0.000***

This table shows the Ljung–Box test statistic (p-value) for examining the null hypothesis of independence in the error term. We try several lag values (1, 2, 3, 4) to see if the conclusion reached changes for different values. If not, then the conclusion is clear, whereas if rejected, then the conclusion is that the data has autocorrelation. The results show that most of the countries have autocorrelation at lag 1, and most of them remain autocorrelated with more lags. Significance level denoted as ***=p<0.01, **=p<0.05, *=p<0.1

Table 25 ARCH-LM test for conditional heteroscedasticity

lag	1	2	4	8	10	12
Austria	0.02311**	0.00041***	0.00028***	0.00033***	0.00084***	0.00070***
Belgium	0.00184***	0.00155***	0.00000***	0.00000***	0.00000***	0.00000***
France	0.01593**	0.00087***	0.00001***	0.00000***	0.00000***	0.00001***
Germany	0.02593**	0.00000***	0.00000***	0.00000***	0.00000***	0.00000***
Greece	0.02777**	0.02760**	0.00086***	0.00629***	0.00340***	0.00173***
Ireland	0.00000***	0.00000***	0.00000***	0.00000***	0.00000***	0.00000***
Italy	0.05387*	0.00000***	0.00000***	0.00000***	0.00000***	0.00000***
Portugal	0.04289**	0.00003***	0.00000***	0.00000***	0.00000***	0.00000***
Spain	0.08203*	0.00000***	0.00000***	0.00000***	0.00000***	0.00000 ***

This table shows the ARCH-LM test statistic (p-value) for examining the null hypothesis of no ARCH effect. Results of different lag length are shown (1, 2, 4, 8, 10, 12) to see if the conclusion reached changes for different values. If the null hypothesis is rejected, there is an ARCH effect in the CDS spreads series. The results show that all countries have ARCH at the 10% level of significance, and the effect becomes stronger with more lags. Significance level denoted as ***=p<0.01, **=p<0.05, *=p<0.1

5.3 Methodology

5.3.1 Multivariate GARCH models

This study looks at the correlations between 9 major EMU countries' CDS markets during the sovereign debt crisis, and hence examines the impacts of policy interventions on these markets. Specifically, it assesses to what extent the policy interventions influenced the dynamics of correlations of sovereign CDS spreads. Most tests measuring correlations and covariances fail to account for their time-varying nature, and generally divide the sample period into sub-samples to examine the impact of policies, causing heteroscedasticity and sub-sample bias.

The dynamic of correlation of several assets can be studied using the multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) model. This model has to be parsimonious as well as interpretable, with positive definiteness of estimated covariance or correlation matrices. The problem with MGARCH models is that they not only increase the number of parameters to be estimated but also complicate the specifications of the conditional variance-covariance matrix. Missio and Watzka (2011) and Silvennoinen and Teräsvirta (2008) provide useful guidance on the choice of MGARCH model. Although several models are feasible technically, interpretation in the context of contagion analysis is suggested to be difficult. These MGARCH models are discussed further below.

The first GARCH model for conditional covariance matrices is the VEC model, proposed by Bollerslev et al. (1988). The VEC operator converts a matrix to a vector by stacking its columns. It is a straightforward generalization of the univariate GARCH model. Each conditional variance and covariance is a function of all lagged conditional variances and covariances, and lagged squared returns and cross-products returns. The original model is computationally very demanding, and anyway often contains too many parameters to be applicable. The simplified version of the model, "diagonal VEC", still contains (p+q+1)N(N+1)/2 parameters. Two main approaches have been used to find more parsimonious alternatives: imposing restrictions on the parameters of the VEC model, including the BEKK and factor models; and modelling conditional covariance through conditional variances and correlations, as in the VC, CCC and DCC-GARCH models.

Engle and Kroner (1995) introduced a model that can directly measure the time-varying covariance, called the Baba-Engle-Kraft-Kroner (BEKK) model. In this model and its generalizations, systems of simultaneous equations are analysed and provide sufficient constraints to allow for the positive definiteness of conditional covariance matrices. The model is feasible in terms of technical correctness and estimation procedures. However, it requires the specification of too many parameters.[30] Moreover, difficulty in interpretation of the estimated parameters makes it inappropriate for contagion analysis.

The factor GARCH model developed by Engle et al. (1990) follows a conditional heteroscedasticity process in estimating the covariance matrices. Its advantage is the simplicity of its estimation procedure, but it has drawbacks in selecting the correct factor for covariance matrices and interpretation of the results.

The constant conditional correlation (CCC) model was proposed by Bollerslev (1990). Its conditional covariance matrix is expressed as $H_t = D_t P D_t$. Unlike other models estimating the covariance matrices directly, it models the conditional variances and conditional correlations instead. A constant conditional correlation

[30] Chiang et al. (2007) show the BEKK model becomes costly in estimation time if expanded to three asset returns.

matrix is estimated by calculating a GARCH estimation for each asset, while the covariance is proportional to the square root of the product of the estimated variance. However, the constant conditional correlation assumption has to be tested (Metiu, 2012), and the model is not suitable for the study of contagion when the correlation is constant, which indicates interdependence.

Due to the intuitive interpretation of correlations, a vast number of studies extend the CCC-GARCH model by specifying the correlation matrix, P_t. Tse and Tsui (2002) proposed the Varying Correlation (VC) model. It ensures the positive definiteness of the correlation matrix by construction. Furthermore, similar to other models, the VC-GARCH model improves the CCC model for extra parameters. However, the number of parameters is N(N+1)/2+2 in each correlation equation, which is a significant weakness when N is large.

As another extension of CCC, the dynamic conditional correlation (DCC) model, introduced by Engle (2002), satisfies all the requirements above. The estimated correlation matrices are positive definite. From a theoretical point of view, the results are easier to interpret, as the correlation dynamics are the key in contagion analysis. From an econometric point of view, the DCC model has three advantages. First, it estimates correlation coefficients of standardized residuals accounting for heteroscedasticity. Second, it allows the inclusion of additional exogenous variables. Third, the model can examine multiple asset returns without adding too many parameters (two parameters for DCC-GARCH), allowing us to process many more correlation-coefficient series in one representation.

5.3.2 Dynamic Conditional Correlation - GARCH model

Let $r_{it} = (r_{1t}, \dots, r_{it})'$ be the vector of interest, changes in CDS spreads in this case. With random disturbance terms, ε_{it}, time-varying covariance matrix H_t and conditional variance equations of h_t, then:

$$r_t = c_0 + \sum_{i=1}^{m} \phi_i r_{t-i} + \sum_{i=1}^{n} \phi_j \varepsilon_{t-i} + \varepsilon_t \tag{21}$$

The dynamic conditional correlation (DCC) [31] allows for the conditional variance-covariance matrix, H_t, to be time-varying. Therefore

$$H_t = D_t R_t D_t = \rho_{ij}\sqrt{h_{iit} h_{jjt}} \tag{22}$$

where D_t is the $(\mathrm{N} \times \mathrm{N})$ diagonal matrix of the time-varying standard deviations from univariate GARCH models with $\sqrt{h_{iit}}$ on the *i*th diagonal; and $R_t = (\rho_{ij})_t$ is the time-varying correlation matrix, which needs to be inverted in calculation at every point, making the process much slower. The dynamic matrix process is modelled by a proxy process, Q_t, as

$$Q_t = (1 - a - b)\bar{Q} + \mathrm{a} z_{t-1} z'_{t-1} + b Q_{t-1} \tag{23}$$

where a and b are non-negative scalars, with constraint $\mathrm{a} + \mathrm{b} < 1$ to ensure stationary and positive definiteness. Q_t is the $(\mathrm{N} \times \mathrm{N})$ time-varying covariance matrix of the standardized error, while $\bar{Q}$ is the unconditional variance matrix of the standardized error, z_t. Since Q_t does not generally have ones on the diagonal, the correlation matrix, *R*, is obtained by rescaling Q_t.

[31] For detailed overview of the MGARCH model, see Chiang et al. (2007), Silvennoinen and Teräsvirta (2008) and Missio and Watzka (2011).

$$R_t = (diag(Q_t))^{-1/2} Q_t (diag(Q_t))^{-1/2} \tag{24}$$

A typical element of R_t is of the form:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}, i,j = 1,2,\dots,\text{n, and } i \neq j \tag{25}$$

For a bivariate case, the correlation could be expressed as follows:

$$\rho_{12,t} = \frac{(1-a-b)\bar{q}_{12} + au_{1,t-1}u_{2,t-1} + bq_{12,t-1}}{\sqrt{(1-a-b)\bar{q}_{11} + au_{1,t-1}^2 + bq_{11,t-1}}\sqrt{(1-a-b)\bar{q}_{22} + au_{2,t-1}^2 + bq_{22,t-1}}} \tag{26}$$

The log-likelihood function can be decomposed into a volatility and correlation component,

$$\begin{aligned} LL &= \frac{1}{2}\sum_{i=1}^{T}(\log(2\pi) + 2log|D_t| + log|R_t| + z_t'R_t^{-1}z_t') \\ &= \frac{1}{2}\sum_{i=1}^{T}(\log(2\pi) + 2log|D_t| + \varepsilon_t'D_t^{-2}\varepsilon_t) \\ &- \frac{1}{2}\sum_{i=1}^{T}(z_t'z_t + log|R_t| + z_t'R_t^{-1}z_t') = LL_V(\theta_1) + LL_R(\theta_1,\theta_2) \end{aligned} \tag{27}$$

where $LL_V(\theta_1)$ is the volatility component with parameters θ_1, and $LL_R(\theta_1,\theta_2)$ is the correlation component with parameters θ_1 and θ_2. The volatility component, the first part of the likelihood function, is the sum of the individual GARCH likelihoods, which can be maximized by separately maximizing each univariate model. The correlation component can be maximized to estimate correlation coefficients.

5.3.3 Model specification

Although the constant correlation GARCH model satisfies the positive-definite condition for the variance-covariance matrix, its validity has to be examined[32]. More importantly, it fails to demonstrate the evolution of correlations over time. Therefore, we propose using Engle's (2002) two-step dynamic conditional correlation GARCH (DCC-GARCH) model.

The specification of a DCC-GARCH model requires the identification of lag order for: the mean model in Eq (21), the variance model in Eq (23), and the distribution model, which is commonly normally distributed, and written as $\epsilon_t|\Omega_{t-1}\sim N(0,H_t)$.

Mean model

To start with, we specify the return equation by fitting an ARMA(m,n) model:

$$r_t = c_0 + \sum_{i=1}^{m} \phi_i r_{t-i} + \sum_{i=1}^{n} \phi_j \varepsilon_{t-i} + \varepsilon_t \qquad (28)$$

where r_t is the return of the variables, which are the changes in CDS spreads in our study, and ϵ_t is the error. The lag-length is selected by minimizing Akaike’s Information Criterion[33], for which we try different orders of ARMA(m,n) models up to ARMA(3,3). The results are shown in Table 26. These indicate MA(1) for Austria, ARMA(2,2) for Belgium, ARMA(3,1) for France, MA(2) for Germany, ARMA(2,2) for Greece, ARMA(2,3) for Ireland, ARMA(1,3) for Italy, AR(3) for Portugal, and ARMA(2,2) for Spain. In addition, the models are checked for no remaining autocorrelation using the Ljung-Box test, the results of which are shown in the last

[32] The CCC assumption is estimated in Appendix 11.
[33] Similar approach is adopted by Missio and Watzka (2011) and Dungey and Martin (2007).

row of Table 26. The test does not reject the hypothesis of no autocorrelation for any of the countries, which justifies the appropriateness of the ARMA() specification.

Variance model

The specification of the GARCH(p,q) order is chosen by minimizing the information criterion (IC). The Akaike information criterion, Bayes information criterion, Shibata information criterion and Hannan-Quinn information criterion are reported in Table 27. The methodology identifies a GARCH(1,1) for most of the cases, despite the fact that there is some conflict between the criteria. Moreover, previous researchers, like Beine (2004), Kodres and Pritsker (2002), Chiang et al. (2007) and Sachs et al. (1996), generally suggest that the simplest GARCH(1,1) specification works reasonably well in capturing the dynamics of variances. Therefore, we have the following variance equation:

$$h_t = c_1 + A_i h_{t-i} + B_i \varepsilon_{t-1}^2 \tag{29}$$

Standardized residuals from GARCH(1,1) for each country are checked for remaining conditional heteroscedasticity using the ARCH-LM test, the results of which are shown in the last column of Table 27. None of them rejects the null hypothesis of no remaining conditional heteroscedasticity, which endorses the appropriateness of the use of GARCH(1,1).

Table 26 ARMA specification

ARMA	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
(1,0)	-2841.44	-3010.96	-3002.57	-2848.02	-2013.92	-3381.87	-2978.81	-3100.86	-3003.06
(0,1)	**-2841.47**	-3010.95	-3002.45	-2848.38	-2013.77	-3381.35	-2977.86	-3095.85	-3003.08
(1,1)	-2840.71	-3009.12	-3000.65	-2850.12	-2012.25	-3381.64	-2977.58	-3098.98	-3001.65
(2,0)	-2839.66	-3009.25	-3000.74	-2852.42	-2013.5	-3381.41	-2978.34	-3099.12	-3002.57
(0,2)	-2839.76	-3009.24	-3000.9	**-2852.81**	-2014.4	-3380.95	-2979.35	-3105.16	-3002.71
(2,1)	-2838.77	-3010.64	-3005.94	-2850.69	-2018.59	-3379.9	-2986.36	-3104.37	-3017.63
(1,2)	-2838.77	-3010.58	-3000.25	-2851.28	-2018.56	-3380.09	-2981.62	-3105.23	-3002.54
(2,2)	-2837.2	**-3010.97**	-3006.98	-2849.83	**-2025.35**	-3395.88	-2985.33	-3111.32	**-3027.71**
(3,0)	-2840.61	-3010.23	-3004.92	-2850.42	-2016.96	-3382.62	-2988.08	**-3113.35**	-3021.17
(0,3)	-2840.61	-3009.74	-3003.17	-2850.95	-2015.59	-3385.14	-2985.2	-3107.13	-3011.12
(3,1)	-2838.96	-3009.92	**-3007.39**	-2848.42	-2015.72	-3389.22	-2986.69	-3112.82	-3025.99
(1,3)	-2839.1	-3009.6	-3006.6	-2849.6	-2015.13	-3389.69	**-2988.5**	-3110.11	-3022.38
(3,2)	-2841	-3010.13	-3005.25	-2847.82	-2020.09	-3401.99	-2987.41	-3111.56	-3025.9
(2,3)	-2841.01	-3009.84	-3005.51	-2847.8	-2020.18	**-3402.45**	-2986.86	-3111.41	-3025.9
(3,3)	-2841.32	-3008.2	-3003.58	-2849.95	-2022.57	-3400.53	-2985.55	-3112.88	-3023.97
p-value	0.99	0.75	1	0.97	0.49	0.98	0.97	0.88	0.92

The mean equation of the GARCH specification is identified by fitting an ARMA(m,n) model, while the lag-length selection is identified via AIC. The model is estimated for up to ARMA(3,3) for each country. The lag with the smallest AIC is chosen and highlighted in bold. Moreover, the remaining autocorrelation in the residual in each respective ARMA() model is examined using the Ljung-Box test. The p-value of the Ljung-Box test is shown in the last row, which does not reject the hypothesis of no autocorrelation.

Table 27 GARCH specification

	GARCH(1,1)	GARCH(1,2)	GARCH(2,1)	GARCH(2,2)	ARCH-LM
Austria					
Akaike	**-3.0864**	-3.0845	-3.0863	-3.0858	0.73
Bayes	**-3.0566**	-3.0498	-3.0516	-3.0461	
Shibata	**-3.0865**	-3.0846	-3.0864	-3.0859	
Hannan-Quinn	**-3.0751**	-3.0713	-3.0731	-3.0707	
Belgium					
Akaike	-3.1645	**-3.1672**	-3.1655	-3.1635	0.55
Bayes	**-3.1198**	-3.1176	-3.1159	-3.1089	
Shibata	-3.1646	**-3.1674**	-3.1657	-3.1637	
Hannan-Quinn	-3.1475	**-3.1484**	-3.1466	-3.1427	
France					
Akaike	-3.1717	-3.1697	-3.1697	**-3.1728**	0.69
Bayes	**-3.1271**	-3.1201	-3.1201	-3.1182	
Shibata	-3.1719	-3.1699	-3.1699	**-3.1730**	
Hannan-Quinn	**-3.1547**	-3.1508	-3.1508	-3.1520	
Germany					
Akaike	-3.0042	-3.0022	-3.0061	**-3.0062**	0.34
Bayes	**-2.9695**	-2.9625	-2.9664	-2.9615	
Shibata	-3.0043	-3.0023	-3.0062	**-3.0063**	
Hannan-Quinn	**-2.9910**	-2.9871	-2.9910	-2.9892	
Greece					
Akaike	**-2.9996**	-2.9969	-2.9971	-2.9944	0.76
Bayes	**-2.9433**	-2.9344	-2.9346	-2.9257	
Shibata	**-2.9999**	-2.9972	-2.9975	-2.9949	
Hannan-Quinn	**-2.9779**	-2.9728	-2.9730	-2.9679	
Ireland					
Akaike	**-3.8073**	-3.8011	-3.8016	-3.8000	0.4
Bayes	**-3.7577**	-3.7465	-3.7470	-3.7405	
Shibata	**-3.8075**	-3.8013	-3.8018	-3.8003	
Hannan-Quinn	**-3.7884**	-3.7803	-3.7808	-3.7774	
Italy					
Akaike	-3.1554	-3.1533	**-3.1651**	-3.1640	0.19
Bayes	-3.1107	-3.1037	**-3.1155**	-3.1094	
Shibata	-3.1555	-3.1535	**-3.1653**	-3.1642	
Hannan-Quinn	-3.1384	-3.1345	**-3.1462**	-3.1432	
Portugal					
Akaike	**-3.4162**	-3.4142	-3.4142	-3.4122	0.78
Bayes	**-3.3765**	-3.3696	-3.3696	-3.3626	
Shibata	**-3.4163**	-3.4144	-3.4144	-3.4124	
Hannan-Quinn	**-3.4011**	-3.3973	-3.3972	-3.3933	
Spain					
Akaike	-3.2200	-3.2180	**-3.2205**	-3.2185	0.34
Bayes	**-3.1754**	-3.1684	-3.1709	-3.1639	
Shibata	-3.2202	-3.2182	**-3.2207**	-3.2187	
Hannan-Quinn	**-3.2030**	-3.1991	-3.2016	-3.1977	

The variance equation of the GARCH specification is identified by minimizing the information criteria. The lag-length is estimated for up to GARCH(2,2) for each country. The lags with the smallest IC for these four ICs are highlighted in bold. The residuals of GARCH(1,1) for each country are checked for remaining conditional heteroscedasticity using the ARCH-LM test, with the p-value of the results shown in the last column. None of them rejects the null hypothesis of no remaining ARCH effect.

5.4 Results

5.4.1 Estimates of the model

Table 28 reports the estimates of the mean and variance equations of the DCC-GARCH model. One can see from the table that most of the AR and MA terms are significant. As $|ar1| > |ar2| > |ar3|$ and $|ma1| > |ma2| > |ma3|$, the lower orders of ARMA(p,q) are shown to have a stronger influence on the return than the higher orders. This suggests that a relatively simple model with few lag orders can effectively capture the dynamic of returns. Moreover, the magnitudes of $|ar|$ are larger than $|ma|$ in most cases, which further explains why AR(1) is a common setup for the GARCH model – see Chiang et al. (2007) and Dungey and Martin (2007). An advantage of this model is the fact that the pairwise correlation coefficients for all 9 countries can be estimated in one single system equation.

In the variance equations, the constant term is less significant and relatively small (less than 0.0005) compared with the other two coefficients. The coefficients for the lagged variance and the shock-squared term are highly significant, which further justifies our specification of GARCH(1,1). Furthermore, the persistence terms (last column), measured as the sum of the coefficients of the lagged variance and the shock-squared term, are close to unity for all 9 cases, implying a high degree of persistent volatility.

Table 29 indicates that the a and b coefficients in Eq (26) are statistically significant at the 10% level for most of pairs, suggesting that the correlations are not constant but time-varying. To confirm this, we employ the Engle and Sheppard (2001)'s Wald test, which evaluates the null hypothesis of constant conditional correlation against dynamic conditional correlation. If a=b=0, the DCC-GARCH model reduces to the

CCC-GARCH model. The p-value of approximately zero rejects the null hypothesis, proving that the time-invariant assumption is too restrictive and that the dynamic correlation structure is necessary.

Table 30 reports the summary statistics for conditional correlation coefficients estimated by the DCC-GARCH model defined in Eq (25) and (26). The mean correlations are generally higher for the PIIGS nations than for the core nations. Moreover, Austria is shown to be the nation least influenced by changes in other countries, while Italy and Spain are the most influenced. The result indicates a tight connection within the PIIGS members.

Specifically, comparing the statistics of the correlation between Greece and other countries, we find that the mean of $\rho_{ij,t}$ is generally above 0.52 for the PIIGS and below 0.51 for the core countries. Italy has the highest correlation with Greece, at 0.5477, followed by Ireland, at 0.5334. In contrast, Austria has only half of that, at 0.2981, which is the lowest of these 8 EMU nations. The minimum correlation reaches 0.0254, between Greece and Austria, while the maximum correlation is 0.7855, between Greece and Portugal.

For Ireland, we find a similar pattern as for Greece. Austria still has the lowest average correlation coefficient, at 0.3505, while other core countries generally have weaker co-movements with Ireland, compared with the other PIIGS. Italy, again, appears to be the most related to Ireland, at 0.6510.

We find the smallest mean value of correlation for Italy is with Austria, at 0.4224. The negative sign in the minimum value of the correlation, between Italy and Austria

(-0.1034), means returns move inversely for the two series. The highest correlation is for the co-movements between Spain and Italy.

The smallest mean correlation for Portugal is also with Austria, at 0.3382. Comparing the average across the whole sample period, we have the following order, from the highest to the lowest: IT, SP, IR, BG, GR, FR, DE and AT.

Among the correlations for Spain, Austria has the lowest, at 0.4060, while Italy has the highest (0.8261), over twice as much as that of Austria.

Table 28 Estimation results for the DCC-GARCH model, first stage

	Mean equations							Variance equations			
	c_0	ar1	ar2	ar3	ma1	ma2	ma3	c_1	A	B	Persistence
Austria	-0.002				0.05			0*	0.045***	0.947***	0.992
	[-1.512]				[1.514]			[1.682]	[3.606]	[78.005]	
Belgium	-0.001	1.067***	-0.224		-0.878***	0.037		0**	0.161***	0.747***	0.908
	[-0.383]	[5.671]	[-1.488]		[-4.589]	[0.25]		[2.294]	[3.145]	[10.836]	
France	0	0.89***	-0.085	-0.08**	-0.728***			0	0.101**	0.884***	0.985
	[-0.306]	[5.284]	[-1.514]	[-2.115]	[-4.311]			[1.165]	[2.318]	[17.507]	
Germany	0				0.129***	-0.016		0.001**	0.151***	0.659***	0.810
	[0.05]				[3.209]	[-0.379]		[2.587]	[3.178]	[7.211]	
Greece	0.003	0.202***	-0.896***		-0.152***	0.94***		0	0.061***	0.938***	0.999
	[1.42]	[5.094]	[-20.969]		[-5.586]	[38.369]		[1.193]	[3.326]	[48.532]	
Ireland	-0.001	-1.101***	-1.001***		1.292***	1.219***	0.197***	0*	0.171**	0.796***	0.977
	[-0.416]	[-163.943]	[-118.663]		[333.016]	[2650.281]	[219.062]	[1.954]	[2.226]	[11.726]	
Italy	-0.001	0.815***			-0.589***	-0.13***	-0.115***	0*	0.133**	0.817***	0.950
	[-0.427]	[6.363]			[-4.337]	[-3.136]	[-2.877]	[1.697]	[2.278]	[10.896]	
Portugal	0	0.234***	0.022	-0.018				0*	0.117***	0.844***	0.961
	[-0.016]	[5.947]	[0.58]	[-0.531]				[1.868]	[2.699]	[15.922]	
Spain	0.001	0.919***	-0.552***		-0.742***	0.421*		0	0.078**	0.907***	0.985
	[0.434]	[4.65]	[-2.879]		[-3.846]	[1.657]		[1.316]	[2.559]	[24.152]	

The estimation results of the mean and variance equations of the DCC-GARCH model are described for each country. The persistence level of the variance is calculated as the sum of coefficients of A and B (A+B). The t-statistics are in parentheses. Significance level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

Mean equation: $r_t = c_0 + \sum_{i=1}^{3} \phi_i r_{t-i} + \sum_{j=1}^{3} \phi_j \epsilon_{t-j} + \epsilon_t$; Variance equation: $h_t = c_1 + A_i h_{t-i} + B_i \varepsilon_{t-1}^2$.

Table 29 Estimation results for the DCC-GARCH, second stage

	AT	BG	FR	DE	GR	IR	IT	PT	SP
Greece									
a	0.082**	0.041*	0.048**	0.043**		0.028	0.052***	0.069*	0.069*
	[2.311]	[1.888]	[2.453]	[2.168]		[1.175]	[2.926]	[1.778]	[1.778]
b	0.904***	0.869***	0.801***	0.834***		0.925***	0.926***	0.593*	0.593*
	[18.622]	[23.202]	[12.439]	[19.991]		[9.884]	[37.554]	[1.763]	[1.763]
Wald test	0.03	0	0	0		0.08	0	0	0
Ireland									
a	0.049***	0.031**	0.015	0.041	0.028		0.019	0.022**	0.012
	[3.403]	[2.359]	[1.502]	[1.375]	[1.175]		[1.507]	[2.043]	[1.089]
b	0.938***	0.939***	0.957***	0.879***	0.925***		0.915***	0.955***	0.944***
	[55.446]	[39.281]	[34.686]	[5.317]	[9.884]		[20.5]	[45.101]	[39.875]
Wald test	0.02	0.01	0.06	0.01	0		0	0	0
Italy									
a	0.054***	0.032	0.013	0.044**	0.052***	0.019		0.013*	0.014
	[5.95]	[1.289]	[1.617]	[2.52]	[2.926]	[1.507]		[1.783]	[1.115]
b	0.943***	0.954***	0.969***	0.881***	0.926***	0.915***		0.972***	0.986***
	[101.746]	[20.52]	[49.961]	[15.76]	[37.554]	[20.497]		[71.299]	[53.095]
Wald test	0	0	0	0.01	0	0		0	0
Portugal									
a	0.039***	0.048*	0.015*	0.03**	0.069*	0.022**	0.013*		0.042***
	[2.766]	[1.741]	[1.65]	[2.167]	[1.778]	[2.043]	[1.783]		[3.353]
b	0.949***	0.912***	0.976***	0.945***	0.593*	0.955***	0.972***		0.935***
	[52.226]	[13.909]	[58.493]	[38.58]	[1.763]	[45.106]	[71.297]		[49.482]
Wald test	0.02	0.01	0	0.01	0	0	0		0
Spain									
a	0.048***	0.088***	0.022*	0.036	0.069*	0.012	0.014	0.042***	
	[4.816]	[3.79]	[1.893]	[0.92]	[1.778]	[1.089]	[1.115]	[3.353]	
b	0.939***	0.872***	0.96***	0.915***	0.593*	0.944***	0.986***	0.935***	
	[76.758]	[20.915]	[44.441]	[6.186]	[1.763]	[39.877]	[53.096]	[49.48]	
Wald test	0.01	0	0.01	0.04	0	0	0	0	

The estimation results of the second stage of the DCC-GARCH model are described for each pairwise relation. The coefficient *a* and *b* in Eq (26) are calculated. The t-statistics are in parentheses. Significance level denoted as ***=p<0.01, **=p<0.05, *=p<0.1. The Wald test proposed by Engle and Sheppard (2001) examines the null hypothesis that a=b=0. The p-value of zero rejects the null hypothesis and indicates the assumption of constant conditional correlation is too restrictive.

Table 30 Summary statistics – DCC

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}$$

	Min	Max	Mean	SD	Skewness	Kurtosis
Greece						
GR-AT	0.0254	0.5233	0.2981	0.0868	-0.114	-0.0405
GR-BG	0.2806	0.7401	0.5079	0.0744	-0.075	0.0199
GR-FR	0.2668	0.7285	0.4464	0.0741	0.5691	0.8217
GR-DE	0.2363	0.6475	0.4190	0.0724	-0.0922	0.1694
GR-IR	0.3278	0.7213	0.5334	0.075	-0.2212	-0.2302
GR-IT	0.3914	0.7505	0.5477	0.0632	-0.049	-0.1359
GR-PT	0.2174	0.7855	0.5262	0.0829	-0.7399	1.7341
GR-SP	0.3215	0.7306	0.5300	0.0868	-0.114	-0.0405
Ireland						
IR-AT	0.0240	0.5719	0.3505	0.1082	-0.5542	0.1611
IR-BG	0.3374	0.7488	0.5713	0.0808	-0.4473	-0.0973
IR-FR	0.2411	0.7049	0.4750	0.0839	0.2068	0.0046
IR-DE	0.1967	0.6638	0.4822	0.0892	-0.3346	0.1121
IR-GR	0.3278	0.7213	0.5334	0.075	-0.2212	-0.2302
IR-IT	0.4745	0.7856	0.6510	0.0667	-0.3653	-0.4676
IR-PT	0.4227	0.8151	0.6140	0.0816	-0.0557	-0.6908
IR-SP	0.4442	0.7967	0.6418	0.0633	-0.3779	-0.2257
Italy						
IT-AT	-0.1034	0.6081	0.4224	0.1308	-1.307	1.6152
IT-BG	0.4938	0.8353	0.7201	0.0664	-0.8821	1.0267
IT-FR	0.3662	0.7667	0.5814	0.0711	-0.1731	-0.1572
IT-DE	0.3024	0.6993	0.5169	0.08	-0.1625	-0.6987
IT-GR	0.3914	0.7505	0.5477	0.0632	-0.049	-0.1359
IT-IR	0.4745	0.7856	0.6510	0.0667	-0.3653	-0.4676
IT-PT	0.3956	0.8301	0.6382	0.079	-0.7339	0.2802
IT-SP	0.6947	0.9074	0.8261	0.0407	-0.5751	0.0631
Portugal						
PT-AT	-0.0782	0.5841	0.3382	0.1129	-0.7443	0.9375
PT-BG	0.3187	0.7633	0.5374	0.0948	-0.2799	-0.7645
PT-FR	0.1119	0.6525	0.4381	0.1035	-0.7638	0.5174
PT-DE	0.1092	0.6217	0.4213	0.1072	-0.641	-0.3677
PT-GR	0.2174	0.7855	0.5262	0.0829	-0.7399	1.7341
PT-IR	0.4227	0.8151	0.6140	0.0816	-0.0557	-0.6908
PT-IT	0.3956	0.8301	0.6382	0.079	-0.7339	0.2802
PT-SP	0.3708	0.7946	0.6363	0.0866	-0.64	-0.3722
Spain						
SP-AT	0.0248	0.6034	0.4060	0.1154	-0.8137	0.218
SP-BG	0.4850	0.8202	0.6696	0.0699	-0.133	-0.2363
SP-FR	0.3211	0.7787	0.5648	0.0746	-0.09	0.3136
SP-DE	0.2941	0.7035	0.5056	0.0806	-0.1392	-0.4794
SP-GR	0.3215	0.7306	0.5300	0.0694	-0.219	0.2883
SP-IR	0.4442	0.7967	0.6418	0.0633	-0.3779	-0.2257
SP-IT	0.6947	0.9074	0.8261	0.0407	-0.5751	0.0631
SP-PT	0.3708	0.7946	0.6363	0.0866	-0.64	-0.3722

5.4.2 Correlation Dynamics

The pairwise correlation dynamics of the 9 Eurozone countries are estimated for each of the countries that experienced financial distress. As Greece was the first to experience a full-scale sovereign debt crisis and is generally considered to be the source of financial contagion, we first examine the pairwise dynamic conditional correlation between Greece and Austria, Belgium, France, Germany, Ireland, Italy, Portugal and Spain. Similar analyses are conducted for Ireland, Italy, Portugal and Spain. Evidence of sovereign credit risk transfer from a troubled country, like Greece, to relatively healthy members will indicated the presence of a spillover effect. If there is no such spillover, the development of Greece's CDS spread variance should be independent of that of other countries. The changes in correlation could also reflect the impact of policy intervention on volatility links[34]. If some countries suffer unjustified financial stress (i.e., solely driven from investor sentiment from bad news regarding other countries), it can be concluded that the financing trouble experienced by some EMU countries is due to a contagion effect.

The correlation dynamics between Greece, Ireland, Italy, Portugal and Spain and the other 8 countries in each instance are shown in Figures 17-21, respectively. These figures plot the daily correlation between variances from 2009 to 2012. The red line representing the dynamic correlation varies over time.

From Figures 17-21, the correlation dynamics graphs, we find a constant pattern for all the countries, although not all of the interventions have exactly the same influence in each case. Most of the policy interventions listed in Table 31 lead to a significant increase in the pairwise correlation. Comparing across countries, correlations with

[34] Similar analysis on dynamic covariance are shown in Appendix 12

Austria and Germany are less volatile and show weaker reactions to these interventions, with less significant peaks, which is consistent with the result shown in Table 30.

At the beginning of the sample period, there is an increase in the correlation for all the countries. It is an artefact of the sampling period, which began shortly after the bank bailout programme was implemented, but before Greece announced its 12.5% deficit. It shows that the banking bailout also had an impact on the interactions between sovereign entities.

The correlation jumps to a new height at the beginning of May 2010, which is about the time of the announcement of Greece's first bailout by the EU and IMF, and peaks at 10 May 2010, which was the setup date of the EFSF, as shown in Table 31. After the policy intervention, the correlations fall back to the normal range as quickly as they peaked, suggesting a temporary reaction. News about Greece served as a strong signal for investor sentiment regarding other countries, which indicates the presence of a spillover effect. The only exception is for Austria, which seems to have been less sensitive to the news. Its low average correlation in Table 30, which suggests a generally weak relation with other countries' CDS spreads, might explain its behaviour[35].

Another high correlation period is between May 2011 and July 2011, which saw the Portugal bailout and the creation of the ESM. During that period, the dynamic correlations are constantly higher than normal, and fall back rapidly after July.

[35] The correlation with Austria reached its lowest point (close to 0) in March 2010 In March, Mr Papandreou proposed a new financial package for Greece and continued to insist that no bailout was needed. By the end of the month, leaders of the euro zone and the IMF agreed upon a deal whereby both parties would provide financial support for Greece.

A fourth period of high correlation is found around the announcement date of the further aid package for Greece by EU leaders at the end of October 2011. The correlations are significantly higher than during normal periods (for France, Germany and Spain, even higher than at the time of the Greece first bailout and the establishment of the EFSF). It further proves the existence of contagion, as this is a reaction to news concerning other countries.

After the date of the Spain bailout, 9 June 2012, the correlations start to climb and reached a new high, especially the correlations with Spanish spread. Around 19 October 2012, the ESM was granted more power to directly recapitalize banks (without routing help through national governments). Again, its announcement leads to a strong reaction in the correlations.

Consistent with the observations made by Chiang et al. (2007), Missio and Watzka (2011) and Kalbaska and Gatkowski (2012), our results indicate a potential contagion effect in the euro market, as defined by Forbes and Rigobon (2002), which is a significant increase in correlation/covariance during a crisis period. Such an increase should be temporary rather than remaining stable at a high level. The periods of significant increase become spikes immediately after the announcement, but quickly fall back to the level before the intervention. The temporary reaction, with a reversion to the normal range, is too fast to be an economically driven increase. Therefore, an intervention-caused contagion effect is suggested for all 8 countries. However, it should be noted that this does not mean that Greece caused the financial troubles of other countries, especially those of the other PIIIGS countries.

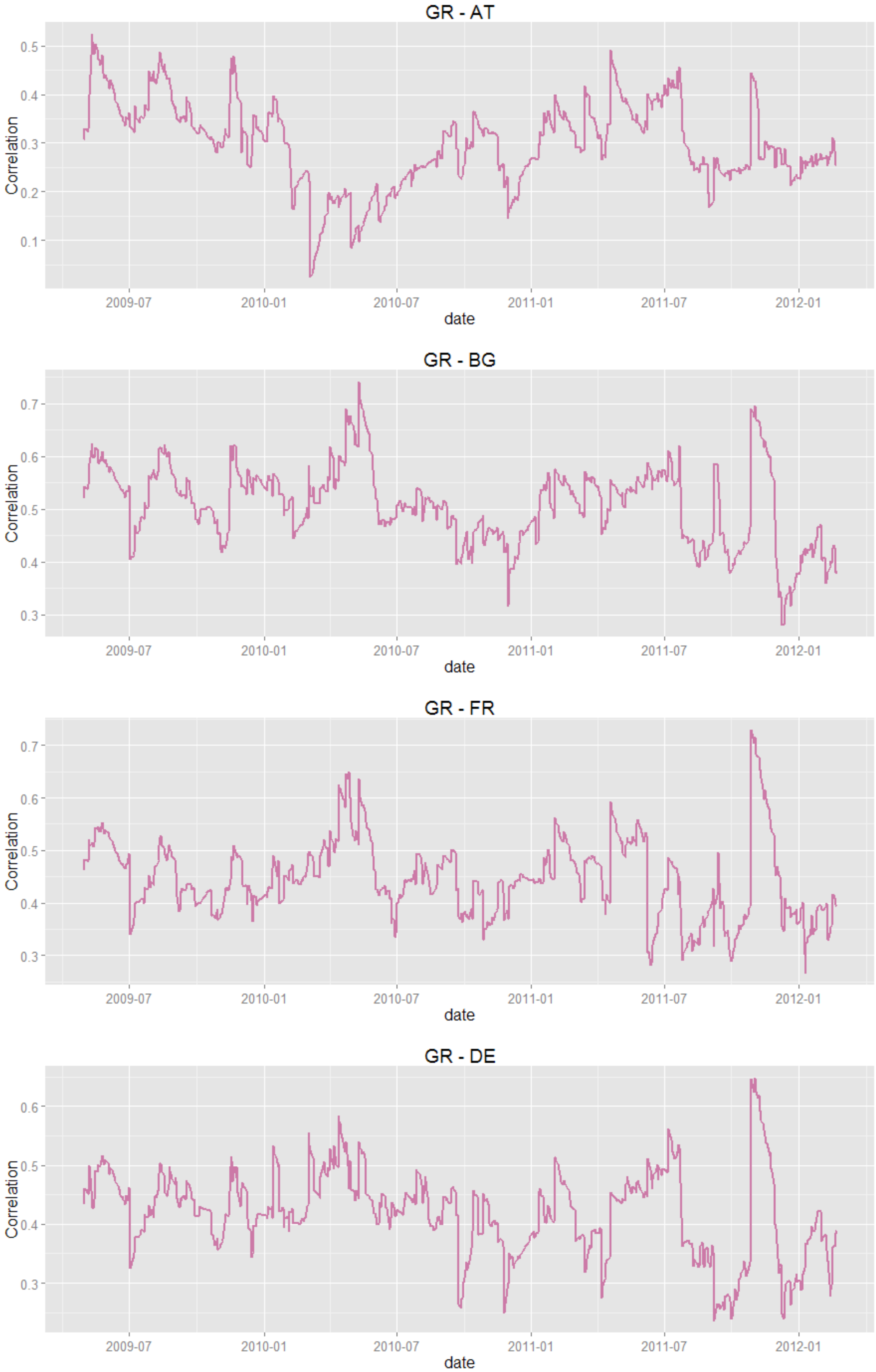
Our interpretation is that through policy interventions, when the increased debt and deficit partly result from assisting other troubled nations, a public-to-public risk transfer occurs. Here, though, there is the potential for a feedback mechanism, as any deterioration in the sovereign creditworthiness of the healthy countries could transmit back to the bailed-out countries, as the rescue plan is a form of credit guarantee. Therefore, “two-way feedback”, proposed by Acharya et al. (2011), is shown as increased correlations between countries.

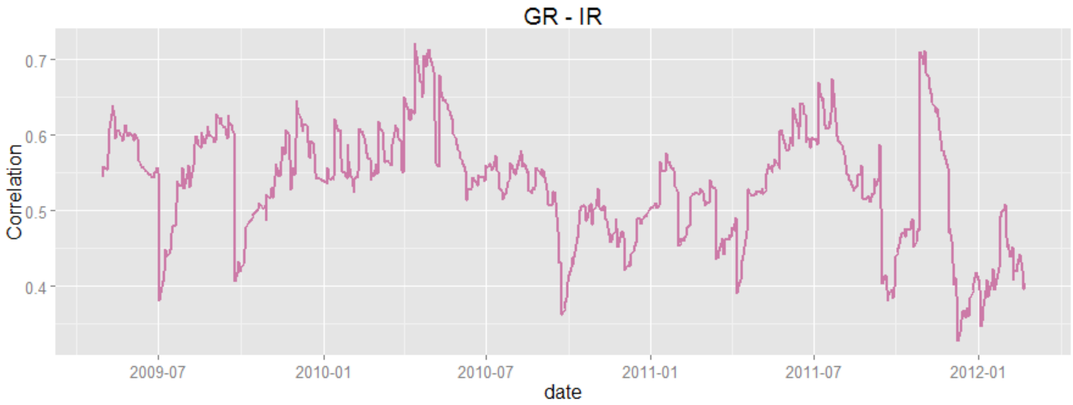
Table 31 Policy intervention events date during the Eurozone sovereign debt crisis

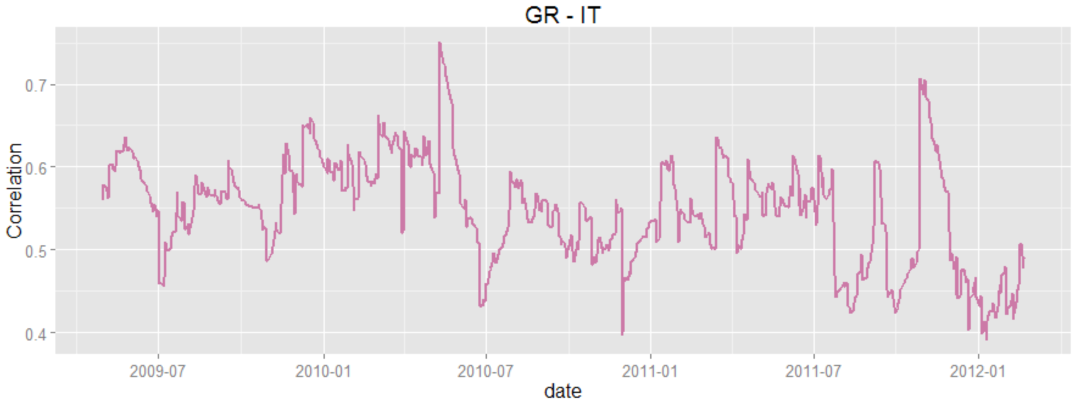
Date	Country	Event
02/05/2010	Greece	EU agrees on a 110 billion-euro rescue package for Greece
10/05/2010	EFSF	Birth of the European Financial Stability Facility, 750 billion euros
28/11/2010	Ireland	Ireland takes a bailout from the IMF, the European Commission and EFSF, totalling about 85 billion euros
16/05/2011	Portugal	The EU and the IMF approve a 78bn-euro bailout for Portugal, funded by the EFSM, EFSF and IMF.
11/07/2011	ESM	The European Stability Mechanism, the permanent bailout fund, is designed to replace the EFSF and the EFSM.
27/10/2011	Greece	The EU agrees extend a new aid package worth 130 billion euros for Greece and a 50% haircut
09/06/2012	Spain	Spain need a 100 bn euro bailout in order to help its failing banks, after Bankia SA is partly nationalized in May
19/10/2012	ESM	EU leaders agree to a single banking supervisor. This agreement clears the way for the ESM to directly recapitalize banks, rather than having to act through national governments.

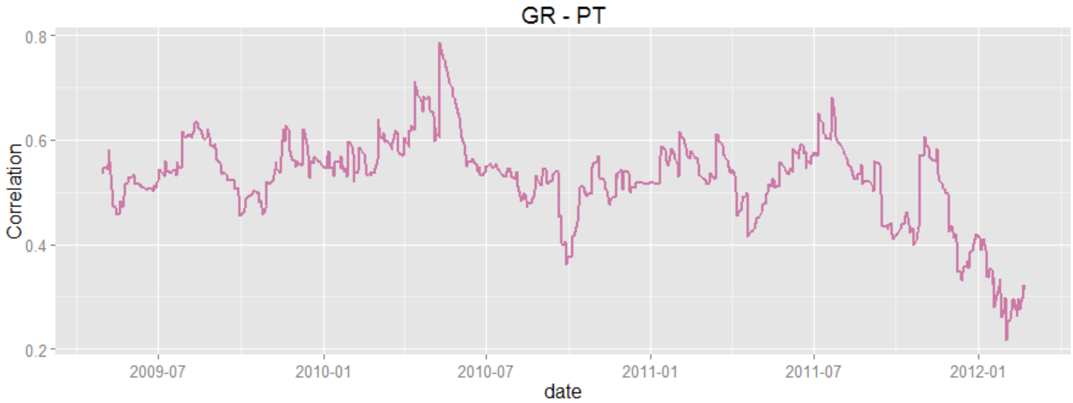
The table presents the list of bailout events in the sovereign debt crisis from 2009 to 2013. A more detailed timeline is presented in Appendix 12.

Figure 17 Correlation dynamics for Greece and other countries




GR - IR
Correlation
0.7
0.6
0.5
0.4
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date


GR - IT
Correlation
0.7
0.6
0.5
0.4
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date


GR - PT
Correlation
0.8
0.6
0.4
0.2
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date

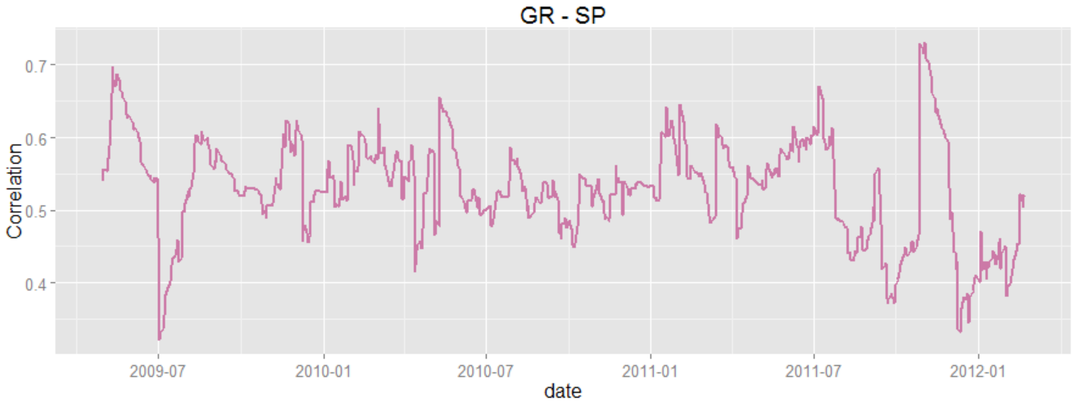
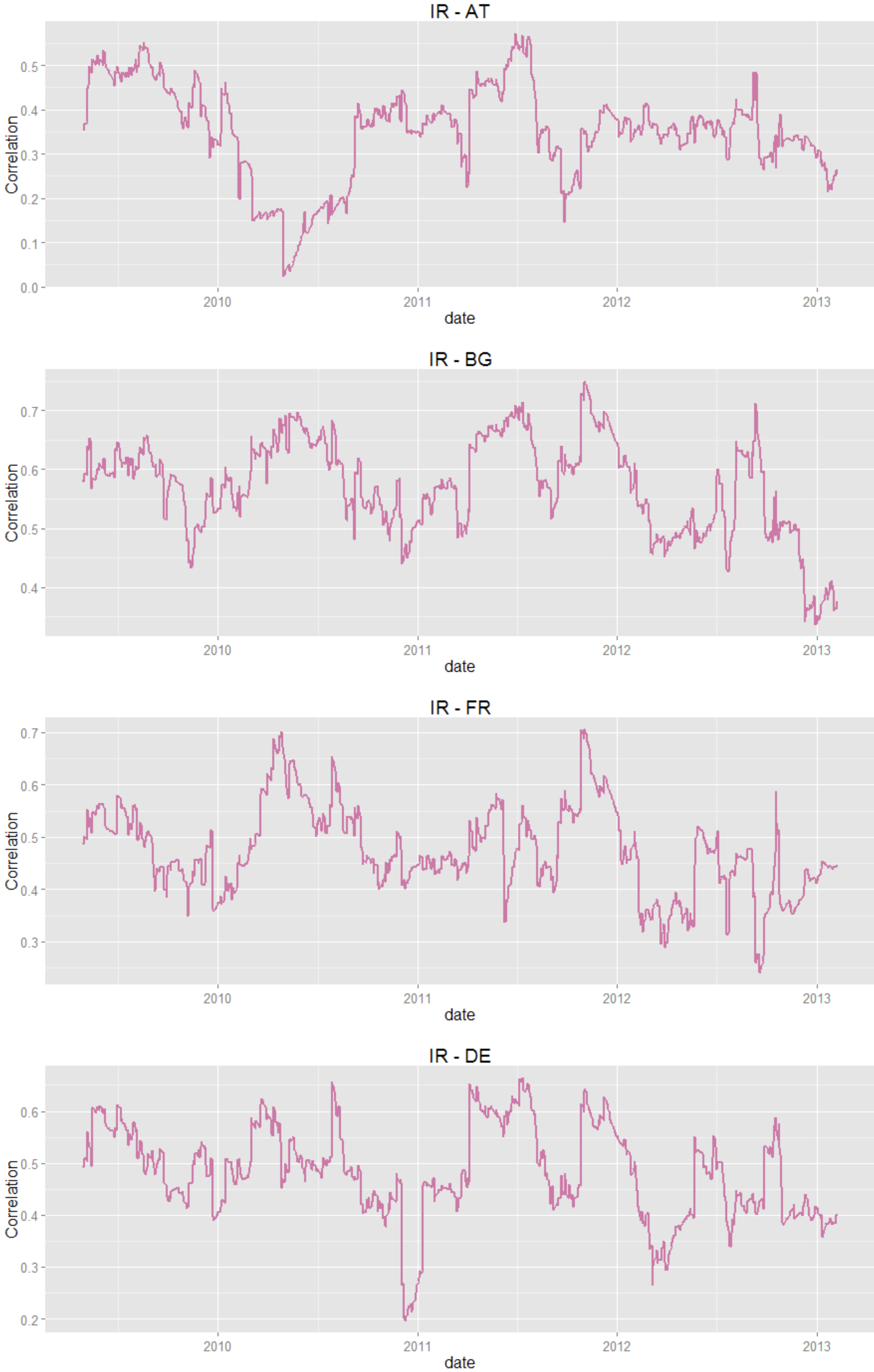
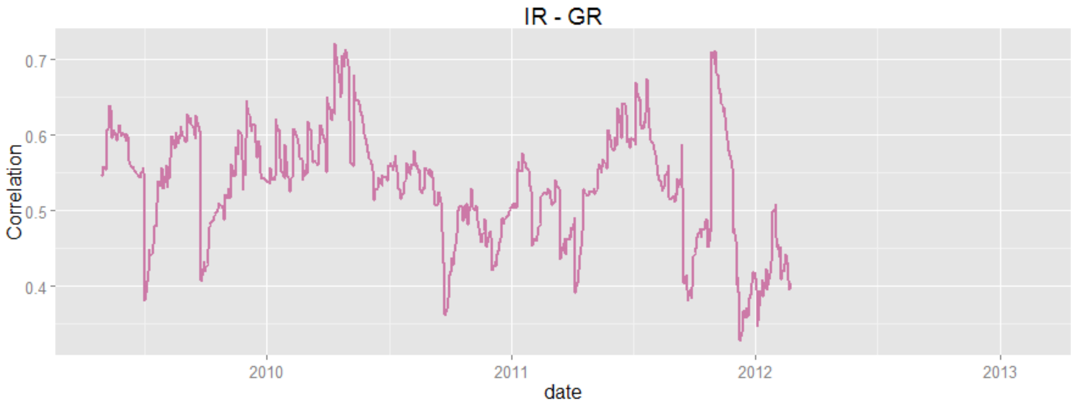
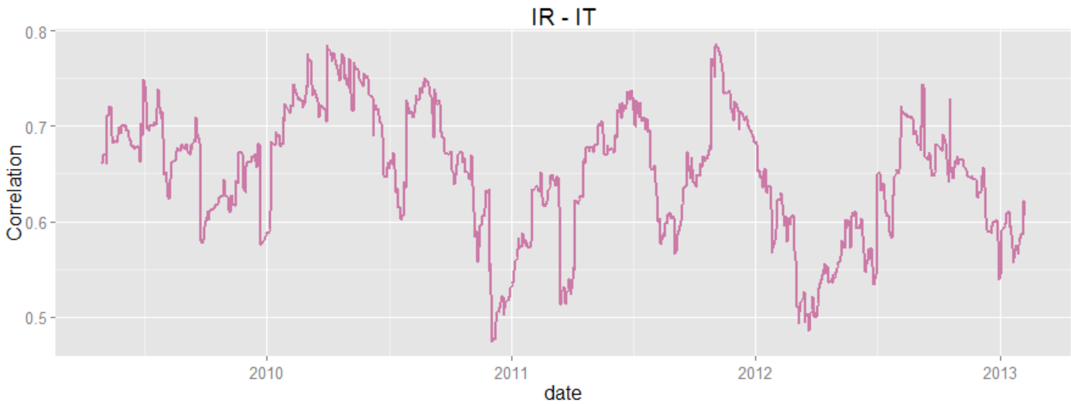
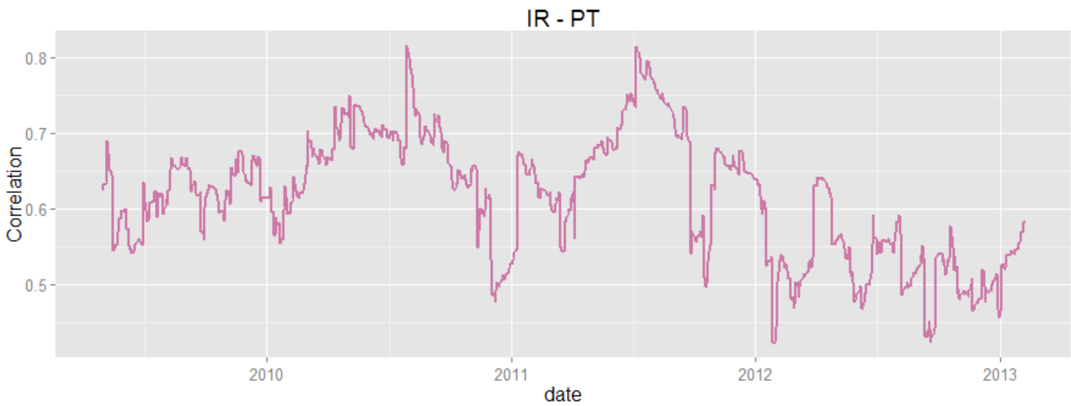

GR - SP
Correlation
0.7
0.6
0.5
0.4
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date

Figure 18 Correlation Dynamics for Ireland and other countries




IR - GR
Correlation
0.7
0.6
0.5
0.4
2010
2011
2012
2013
date


IR - IT
Correlation
0.8
0.7
0.6
0.5
2010
2011
2012
2013
date


IR - PT
Correlation
0.8
0.7
0.6
0.5
2010
2011
2012
2013
date

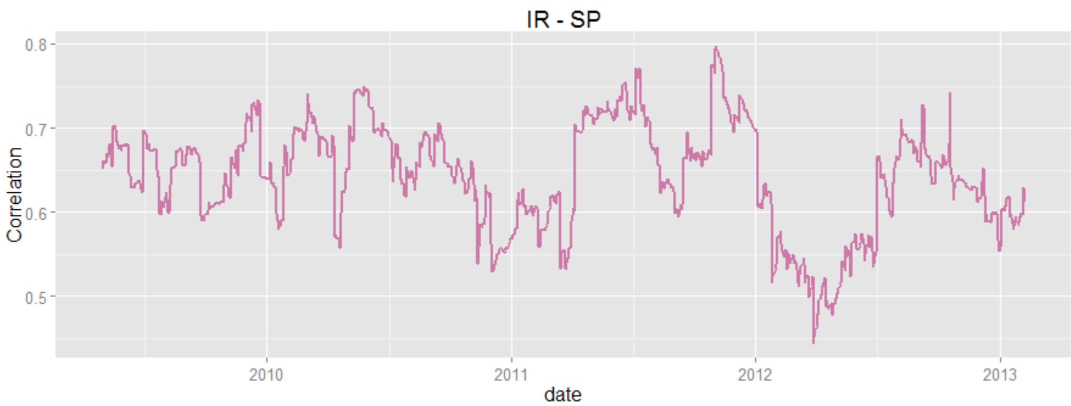
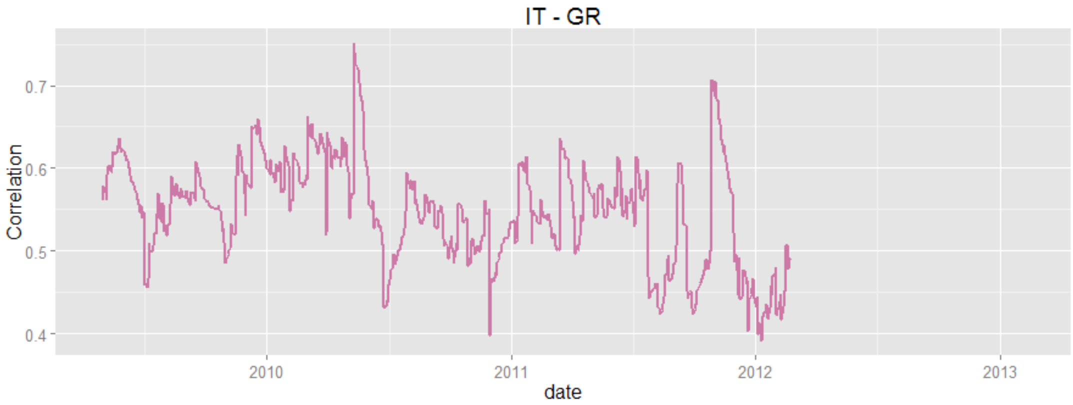
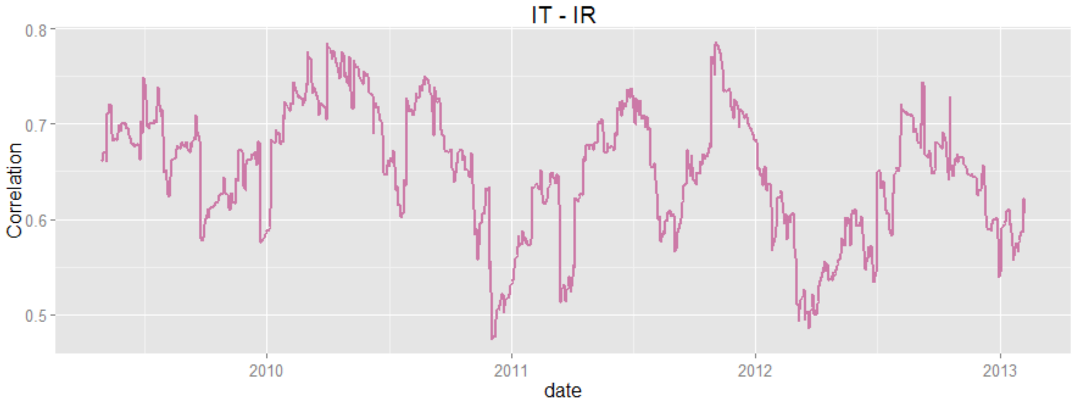
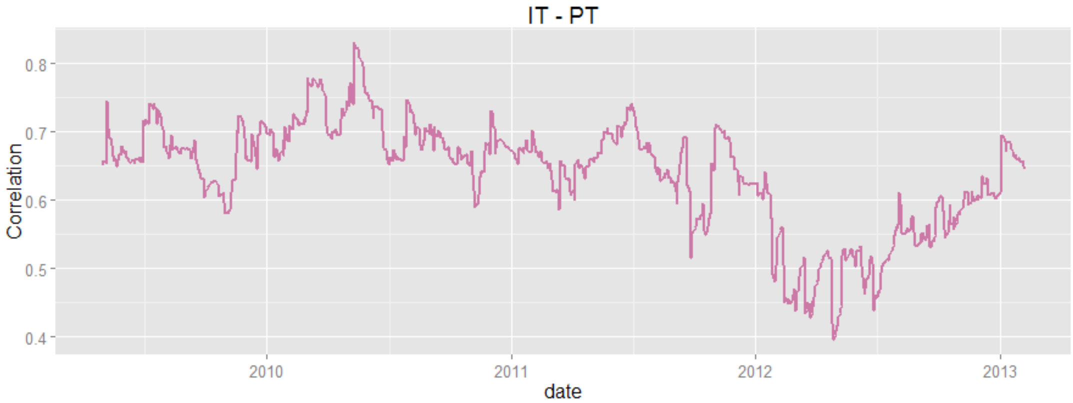

IR - SP
Correlation
0.8
0.7
0.6
0.5
2010
2011
2012
2013
date

Figure 19 Correlation Dynamics for Italy and other countries


IT - GR
Correlation
0.7
0.6
0.5
0.4
2010
2011
2012
2013
date


IT - IR
Correlation
0.8
0.7
0.6
0.5
2010
2011
2012
2013
date


IT - PT
Correlation
0.8
0.7
0.6
0.5
0.4
2010
2011
2012
2013
date

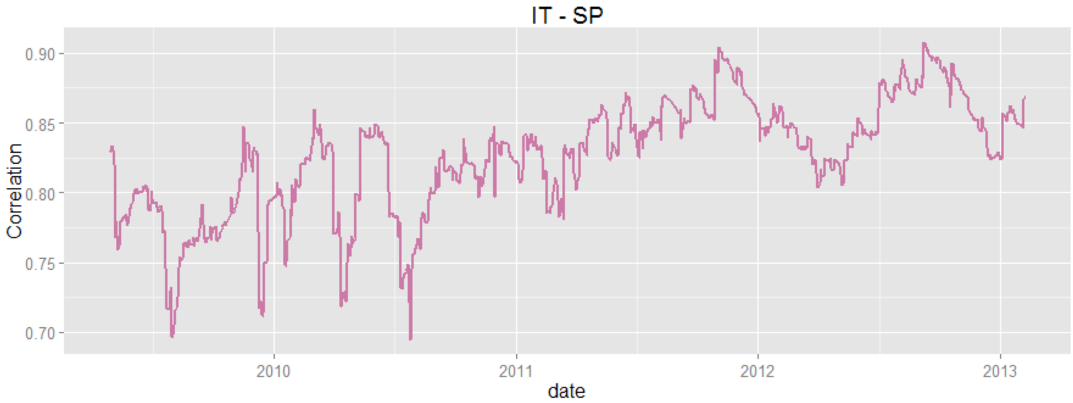
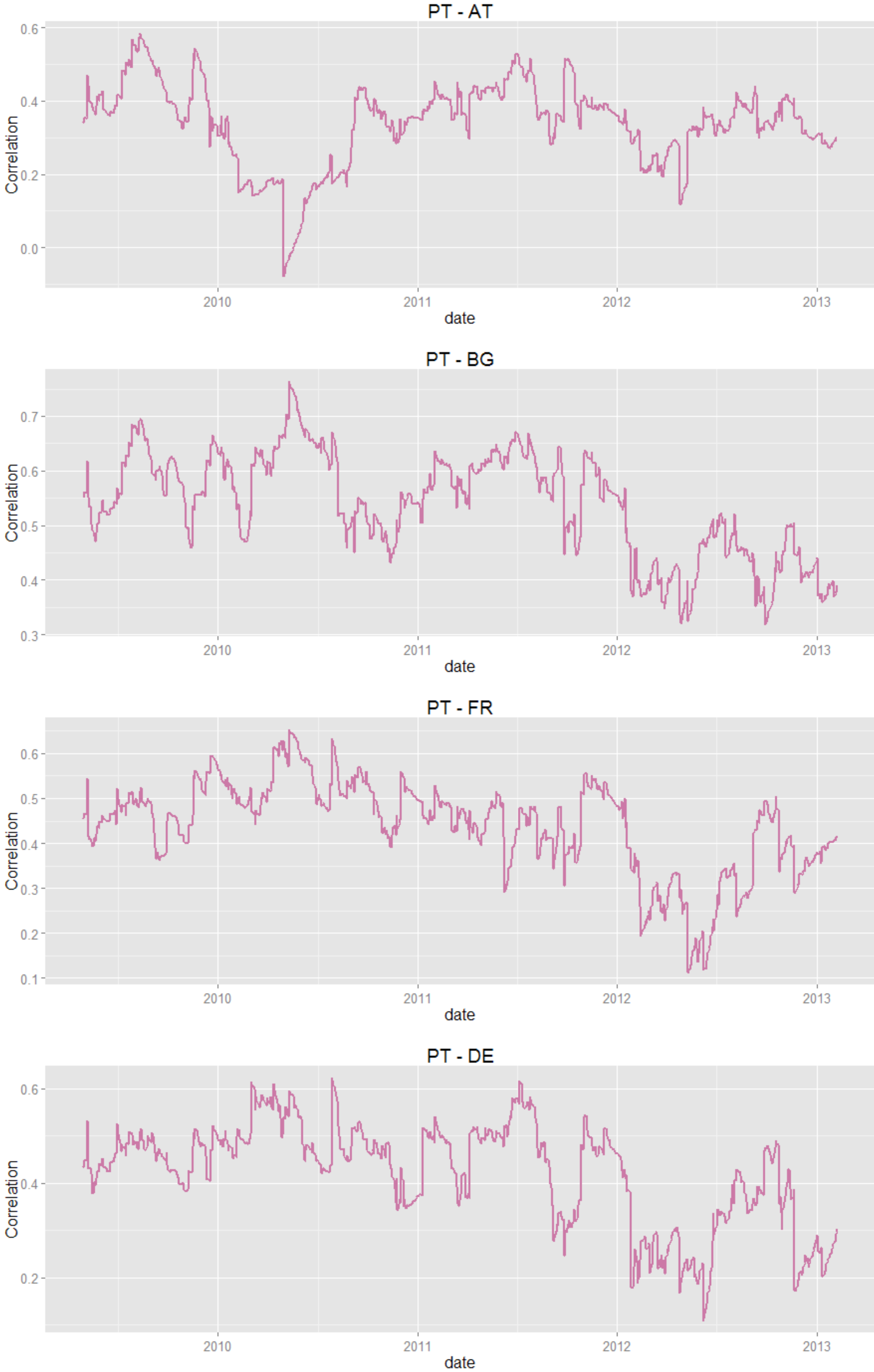
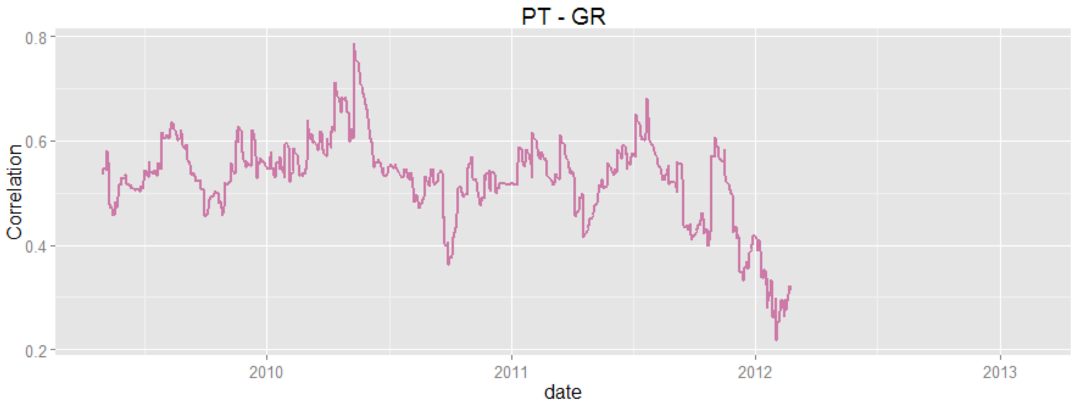
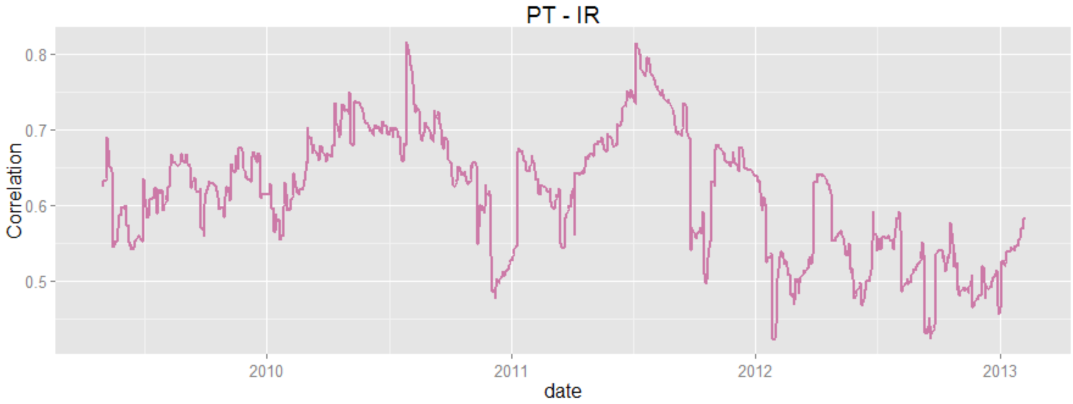
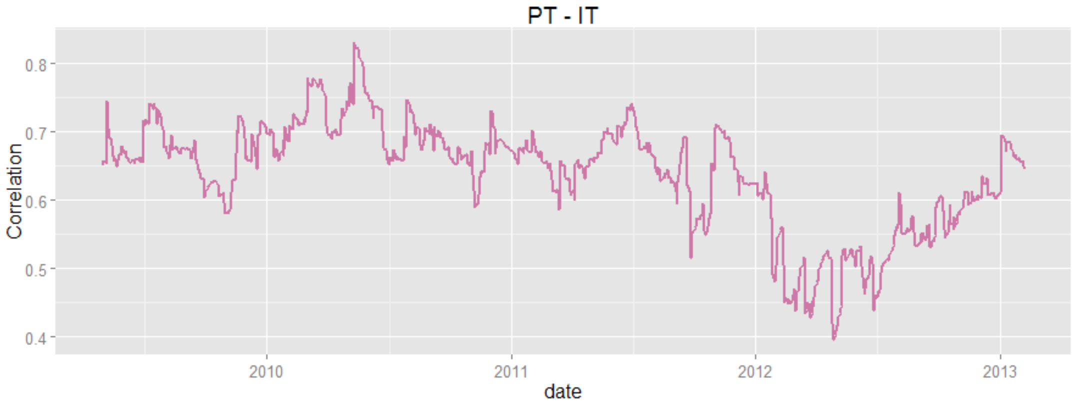

IT - SP
Correlation
0.90
0.85
0.80
0.75
0.70
2010
2011
2012
2013
date

Figure 20 Correlation Dynamics for Portugal and other countries




PT - GR
0.8
0.6
0.4
0.2
Correlation
2010
2011
2012
2013
date


PT - IR
0.8
0.7
0.6
0.5
Correlation
2010
2011
2012
2013
date


PT - IT
0.8
0.7
0.6
0.5
0.4
Correlation
2010
2011
2012
2013
date

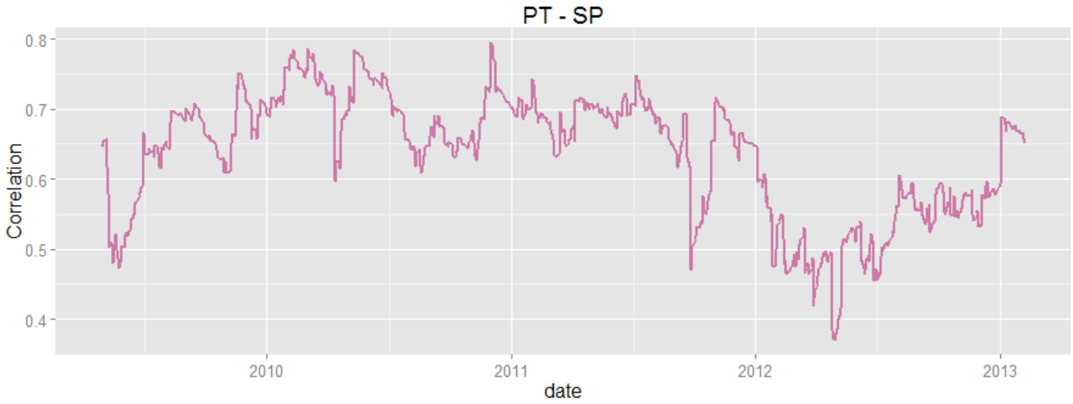
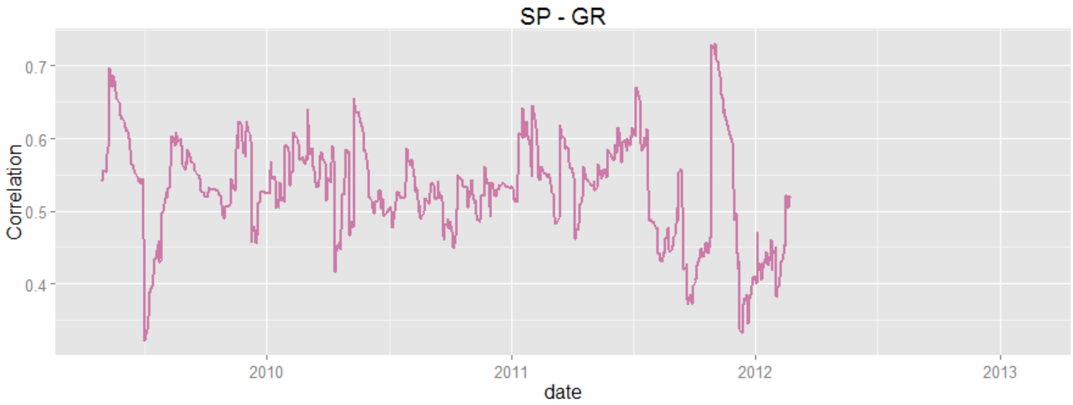
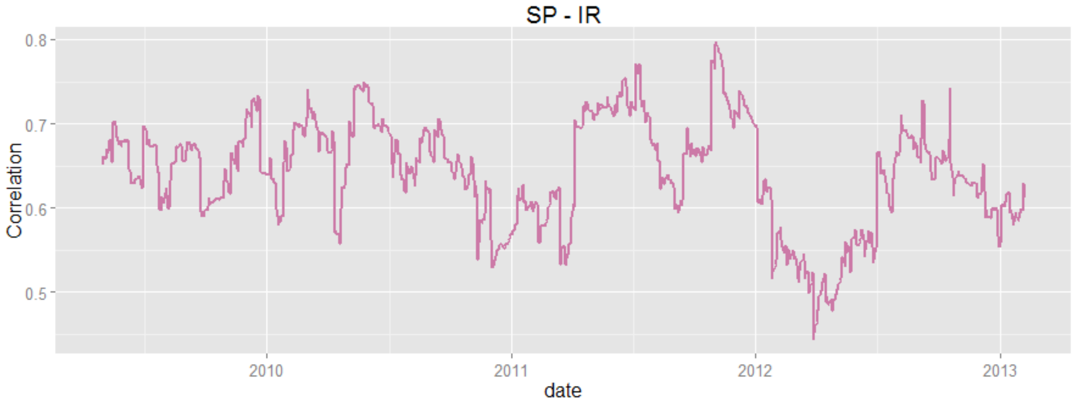
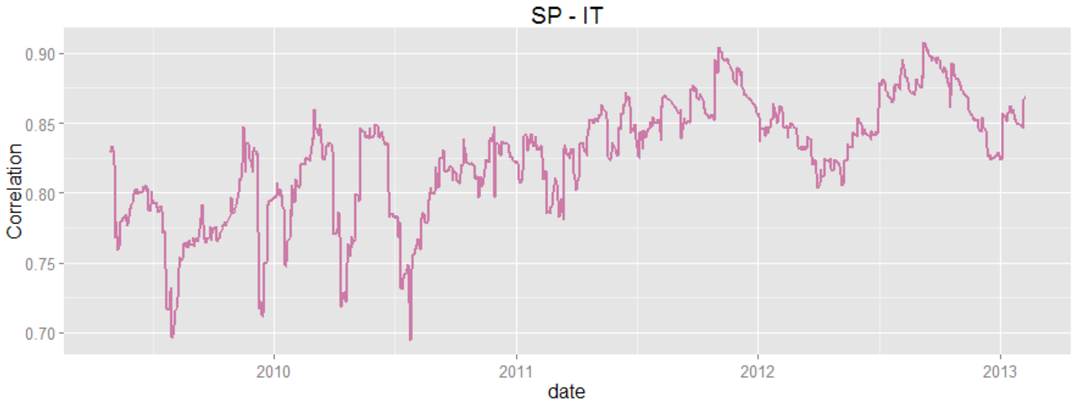
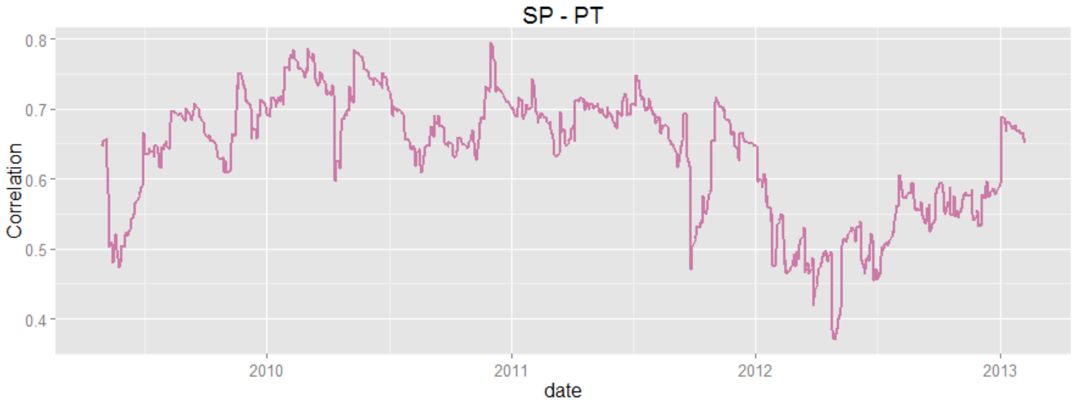

PT - SP
0.8
0.7
0.6
0.5
0.4
Correlation
2010
2011
2012
2013
date

Figure 21 Correlation Dynamics for Spain and other countries


SP - GR
Correlation
0.7
0.6
0.5
0.4
2010
2011
2012
2013
date


SP - IR
Correlation
0.8
0.7
0.6
0.5
2010
2011
2012
2013
date


SP - IT
Correlation
0.90
0.85
0.80
0.75
0.70
2010
2011
2012
2013
date


SP - PT
Correlation
0.8
0.7
0.6
0.5
0.4
2010
2011
2012
2013
date

5.4.3 Announcement effects

As shown in Figures 17-21, the pairwise conditional correlation coefficients between sovereign CDS spreads variance of the euro markets were seen to be volatile during the sovereign debt crisis period, and were strong reactions to the policy interventions listed in Table 31. The high volatility of these correlations indicates that the estimation of correlation is less reliable, and casts doubt on the efficiency of market portfolio diversification (which relies on estimating such correlation coefficients). However, it is still unclear how much the policy interventions affected these correlations. To determine this, it is necessary to look into the time-series behaviour of the correlations and to capture the impact of external shocks on their movements.

It should be noted that these correlation coefficients are sensitive to both local and global news. In order to analyse the contagious effects of policy intervention announcements, we regress the condition correlation between variances on a dummy variable of policy intervention, which is set to be 1 if an intervention was announced at that date, and zero if not. Furthermore, as shown in Chapter 4, the effect of the VIX, has a significant influence on the sovereign CDS spreads of EU countries. In addition, sovereign credit ratings changes for a particular country (Greece, Ireland, Italy, Portugal, Spain) are used to test the impact of rating news on correlations[36].

[36] One might argue that correlation changes are not due to rating announcements. It is not caused by the announcement itself nor driven by irrational investor sentiment, but by rational investors' anticipation of an increased likelihood of a potential changes. For example, Ireland is anticipated by investors to experience a rating cut shortly after Greece has received one. The worsened refinancing conditions of Ireland do not result from announcement contagion, but from fundamental factors.

$$\rho_{ij,t} = c_0 + \sum_{p=1}^{m} \phi_i \rho_{ij,t-p} + \sum_{q=1}^{n} \phi_k \varepsilon_{t-q} + \sum_{s=-1}^{1} \alpha_1 I_{t-s} + \beta_1 vix_{t-1} + \varphi_1 R_{i,t-1} + \varphi_2 R_{j,t-1} + \varphi_3 O_{i,t-1} + \varphi_4 O_{j,t-1} + \varepsilon_t \quad (30)$$

where $\rho_{ij,t}$ is the pairwise correlation between variances in sovereign CDS market. I_{t-s} is the intervention variable for measuring the policy intervention events at time t, with a window length of *s*, covering from (*T-1*) to (*T+1*). vix_{t-1} is the one-day lag of the US market S&P 500 index volatility. $R_{i,t-1}/O_{i,t-1}$ and $R_{j,t-1}/O_{j,t-1}$ are used to capture the effect of sovereign credit rating/outlook changes (one-day lag) in the correlation between domestic country, *i* (Greece, Ireland, Italy, Portugal and Spain), and foreign country, *j* (other 8 countries correlated with country *i*). When a country experiences a rating or outlook change, announced by any of the three rating agencies, the rating variable is set accordingly, similarly defined as in Eq (13). The lag length is selected by AIC.

Since our ARCH-LM test in Table 33 finds significant heteroscedasticity in all cases, the conditional covariance equation is assumed to follow a GARCH(1,1) specification[37].

$$h_{ij,t} = c_1 + A_i h_{ij,t-i} + B_i \varepsilon_{ij,t-1}^2 \quad (31)$$

where $h_{ij,t}$ is the pairwise covariance between countries *i* and *j*.

The ARMA lag length selection results are shown in Table 34. These indicate AR(1) for all of the pairwise relations. The estimates using the maximum-likelihood method for the GARCH(1,1) model are reported in Table 32. Panels A, B, C, D and E show

[37] Following Chiang et al. (2007), Missio and Watzka (2011) and Min and Hwang (2012), no external volatility is included in the variance equation. We reject the assumption that the variance of correlation between variances is sensitive to local and global news. Bensafta and Semedo (2013) suggest that the external repressor in the variance equation has to be unanticipated events.

the correlations with Greece, Ireland, Italy, Portugal and Spain respectively. The results show that the spillover from the US market (VIX) is insignificant, with coefficients less than 0.001, suggesting that the US market did not have much impact on the correlations between EMU countries during debt crisis.

In terms of the focus of this study, the impact of policy intervention, the evidence shows that most of the markets were negatively influenced by the policy interventions, among which, intervention at day *t* is found to be the most significant factor in affecting the dynamic conditional correlations between variances. In addition, interventions at *t-1* and *t+1* demonstrate less significant but still strong impacts on most of the pairwise DCC. However, it should be noted that these influences are positive in many cases. One possible reason for the different sign on the correlation coefficient is the different speed in reacting to announcements (Chiang et al. 2007). Since the intervention variable is constructed as the sum of all policy interventions in the region, listed in Table 31, the universal high sensitivity of pairwise correlations to interventions in other countries indicates a contagion effect. It provides evidence for the argument that investors in the EMU countries were generally concerned about any intervention, including bailout plans and rescue funds, in the region.

With respect to the impact of sovereign credit rating and outlook changes on correlations, the statistics show that there is no statistically significant influence (for both domestic and foreign), with coefficients less than 0.01 in most cases. Nevertheless, comparing the influence from ‘domestic’ and ‘foreign’ country, rating and outlook changes in the domestic country is found to be more influential. The coefficients of “rating domestic” on IR-AT, IT-AT, IT-PT, PT-DE, PT-IR, PT-SP and SP-AT are statistic significant, while those of “rating foreign” have similar impacts on the correlations for IR-PT, PT-AT and PT-FR. This suggests that investors are more sensitive to sovereign credit status changes in the domestic country, in this case the PIIGS countries. This is reasonable considering that the development of the sovereign debt crisis mainly affected the financially distressed countries. In addition, the finding also supports our assumption in Chapter 4 that the influence of the CDS spreads of one country depends on its “information”, and indeed the PIIGS countries generally have larger uncertainty and are more informative. Furthermore, outlook change is shown to be a stronger factor in affecting the DCC, compared with rating change, as the coefficients of outlook changes in the domestic country on IT-AT, IR-FR, PT-SP, SP-AT and SP-FR are significant at the 1% level. This finding is in line with the suggestion that outlook has a strong impact on sovereign CDS spreads in Chapter 4.

Putting the information together, our empirical analysis suggests that announcements about policy interventions have a significant and consistent impact on pairwise cross-market correlations during the sovereign debt crisis. Nevertheless, compared with the strong influence of intervention, credit rating/outlook and VIX do not show much impact on the dynamic conditional correlation between the variances of EMU countries, although they are proven to be a significant factor affecting sovereign CDS spreads in previous chapter. This result suggests that policy interventions play the most direct and significant role in shaping the structure of dynamic correlations in EMU markets.

Table 32 Test of influence of policy intervention on DCC

Panel A	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Greece									
c0	0.304***	0.512***	0.454***	0.424***		0.537***	0.543***	0.531***	0.533***
	[18.2]	[36.166]	[35.767]	[33.052]		[36.475]	[48.864]	[33.219]	[42.011]
ar1	0.965***	0.955***	0.941***	0.942***		0.96***	0.949***	0.978***	0.946***
	[99.365]	[87.068]	[72.859]	[75.305]		[89.157]	[91.22]	[114.079]	[78.428]
vix	0	0	0	0		0	0	0	0
	[-1.553]	[-0.524]	[-0.557]	[-1.039]		[-0.256]	[-0.043]	[-0.444]	[-1.423]
Intervention(t-1)	-0.001	0.023***	0.026***	0.022**		0.027***	0.013	0.022***	0.043***
	[-0.159]	[2.739]	[2.754]	[2.493]		[3.444]	[1.354]	[3.223]	[5.238]
Intervention(t)	-0.016***	-0.012	-0.04***	-0.031***		-0.024***	-0.034***	-0.02**	-0.019**
	[-3.737]	[-1.313]	[-3.748]	[-3.071]		[-2.698]	[-5.416]	[-2.526]	[-2.038]
Intervention(t+1)	-0.019**	-0.008	-0.018*	-0.019**		-0.012	0.028***	-0.013*	-0.009
	[-2.371]	[-1.036]	[-1.915]	[-2.117]		[-1.5]	[4.258]	[-1.853]	[-1.052]
Rating home	0.001	0	0.002	0		0.001	-0.002	0	0
	[0.363]	[-0.026]	[1.172]	[0.219]		[0.482]	[-1.318]	[0.14]	[0.076]
Rating foreign	0.003	-0.006	0.002	0.002		0	-0.006	0.003	-0.001
	[0.194]	[-0.775]	[0.085]	[0.168]		[-0.159]	[-1.559]	[1.332]	[-0.239]
Outlook home	-0.002	0	0.004	0.001		-0.005	0.007	0	-0.004
	[-0.218]	[-0.045]	[0.481]	[0.166]		[-0.734]	[1.155]	[-0.013]	[-0.561]
Outlook foreign	-0.006	0.006	0.001	-0.001		-0.001	0.013	0.003	0.003
	[-0.403]	[0.602]	[0.069]	[-0.057]		[-0.084]	[1.439]	[0.592]	[0.331]
c1	0***	0***	0	0***		0***	0***	0***	0***
	[5.448]	[24.727]	[1.618]	[20.097]		[8.36]	[12.885]	[13.247]	[2.694]
A	0	0	0.003*	0		0	0.457***	0	0
	[0]	[0]	[1.896]	[0]		[0.001]	[5.301]	[0]	[0]
B	0.972***	0.999***	0.996***	0.999***		0.98***	0.09**	0.999***	0.955***
	[179.831]	[14013.403]	[1912.865]	[12908.252]		[424.663]	[2.557]	[12540.785]	[58.331]

Panel B	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Ireland									
c0	0.351***	0.577***	0.49***	0.487***	0.537***		0.657***	0.622***	0.647***
	[18.555]	[39.044]	[46.381]	[30.576]	[36.475]		[55.373]	[43.686]	[57.175]
ar1	0.99***	0.982***	0.969***	0.974***	0.96***		0.975***	0.978***	0.971***
	[178.105]	[146.016]	[161.894]	[133.488]	[89.157]		[135.574]	[147.114]	[127.409]
vix	0	0	0	0	0		0	0	0
	[-1.161]	[-0.957]	[-0.108]	[-0.333]	[-0.256]		[-0.871]	[-0.838]	[-0.976]
Intervention(t-1)	0.002	0.002	0.016**	0.001	0.027***		0	0.003	0.005
	[0.315]	[0.317]	[2.457]	[0.121]	[3.444]		[-0.095]	[0.56]	[1.047]
Intervention(t)	-0.011***	-0.007	-0.018***	-0.02***	-0.024***		-0.005	-0.007**	-0.011**
	[-3.372]	[-1.138]	[-3.224]	[-2.746]	[-2.698]		[-0.915]	[-2.203]	[-2.098]
Intervention(t+1)	-0.037***	0.003	0.011*	-0.012*	-0.012		0.004	-0.005	0.003
	[-6.333]	[0.516]	[1.736]	[-1.842]	[-1.5]		[0.812]	[-0.914]	[0.538]
Rating home	-0.003*	0	-0.001	-0.002	0.001		-0.001	-0.002	0
	[-1.949]	[0.266]	[-0.706]	[-0.931]	[0.482]		[-0.915]	[-1.043]	[-0.254]
Rating foreign	-0.012	0.002	-0.006	-0.003	0		0.001	0.003*	-0.002
	[-0.946]	[0.384]	[-0.958]	[-0.268]	[-0.159]		[0.339]	[1.824]	[-1.413]
Outlook home	0.017***	0.005	0.013***	0.002	-0.005		0	0	0.002
	[2.967]	[0.867]	[3.214]	[0.307]	[-0.734]		[-0.094]	[0.081]	[0.464]
Outlook foreign	-0.002	0	0.002	0.011	-0.001		0.001	-0.005	0
	[-0.257]	[-0.003]	[0.375]	[0.958]	[-0.084]		[0.213]	[-1.084]	[0.091]
c1	0***	0***	0***	0***	0***		0***	0	0***
	[4.366]	[2.83]	[8.337]	[3.019]	[8.36]		[6.137]	[0.597]	[5.897]
A	0.11**	0.002	0.67***	0	0		0	0	0
	[2.326]	[0.522]	[4.495]	[0]	[0.001]		[0.003]	[0]	[0.001]
B	0.654***	0.967***	0.238***	0.952***	0.98***		0.935***	0.938***	0.956***
	[8.301]	[86.888]	[3.596]	[60.346]	[424.663]		[544.374]	[9.114]	[202.508]

Panel C	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Italy									
c0	0.417***	0.723***	0.585***	0.522***	0.543***	0.657***		0.65***	0.835***
	[22.272]	[69.024]	[46.288]	[36.715]	[48.864]	[55.373]		[49.136]	[99.154]
ar1	0.988***	0.988***	0.965***	0.974***	0.949***	0.975***		0.983***	0.981***
	[203.34]	[160.996]	[112.473]	[132.787]	[91.22]	[135.574]		[160.599]	[143.69]
vix	-0.001**	0	0	0	0	0		0	0***
	[-2.344]	[0.061]	[-0.131]	[-0.072]	[-0.043]	[-0.871]		[-1.132]	[-3.192]
Intervention(t-1)	0.002	0.01**	0.012**	0.003	0.013	0		0.001	0.004
	[0.252]	[2.482]	[2.074]	[0.481]	[1.354]	[-0.095]		[0.165]	[1.501]
Intervention(t)	-0.043***	-0.015***	0	-0.002	-0.034***	-0.005		-0.014***	-0.002
	[-6.087]	[-3.343]	[0.013]	[-0.228]	[-5.416]	[-0.915]		[-2.671]	[-0.736]
Intervention(t+1)	-0.046***	-0.006*	0.004	-0.002	0.028***	0.004		-0.002	0.001
	[-7.485]	[-1.652]	[0.681]	[-0.371]	[4.258]	[0.812]		[-0.428]	[0.571]
Rating home	-0.008**	0	0.003	0.003	-0.002	0.001		-0.005*	0.001
	[-2.108]	[-0.203]	[0.859]	[0.959]	[-1.318]	[0.339]		[-1.664]	[1.141]
Rating foreign	0.001	0.001	-0.014	0	-0.006	-0.001		0	-0.001
	[0.088]	[0.248]	[-1.374]	[0.037]	[-1.559]	[-0.915]		[0.021]	[-0.897]
Outlook home	0.011	-0.004	-0.003	0.004	0.007	0.001		0.002	-0.001
	[1.173]	[-0.845]	[-0.329]	[0.494]	[1.155]	[0.213]		[0.261]	[-0.326]
Outlook foreign	0	-0.002	-0.002	0.012	0.013	0		0.001	0.009***
	[-0.006]	[-0.42]	[-0.233]	[1.071]	[1.439]	[-0.094]		[0.197]	[3.348]
c1	0	0***	0***	0***	0***	0***		0***	0*
	[0.501]	[3.429]	[8.178]	[5.139]	[12.885]	[3.854]		[8.679]	[1.883]
A	0	0.013***	0	0	0.457***	0		0.005**	0.008***
	[0]	[74.807]	[0.017]	[0.006]	[5.301]	[0.003]		[2.006]	[8.284]
B	0.916***	0.972***	0.977***	0.997***	0.09**	0.935***		0.977***	0.99***
	[5.472]	[129.181]	[516.883]	[1112.869]	[2.557]	[71.368]		[466.455]	[1886.009]

Panel D	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Portugal									
c0	0.34***	0.546***	0.452***	0.429***	0.531***	0.622***	0.65***		0.647***
	[18.566]	[35.344]	[26.112]	[23.031]	[33.219]	[43.696]	[49.134]		[43.229]
ar1	0.983***	0.986***	0.982***	0.98***	0.978***	0.978***	0.983***		0.987***
	[168.539]	[174.659]	[162.835]	[150.337]	[114.079]	[147.1]	[160.625]		[173.313]
vix	0	0	0	0	0	0	0		0
	[-0.799]	[-0.441]	[-0.257]	[-1.18]	[-0.444]	[-0.845]	[-1.132]		[-1.466]
Intervention(t-1)	0.002	0.005	0.006	0.009	0.022***	0.003	0.001		0
	[0.254]	[0.975]	[1.031]	[1.304]	[3.223]	[0.563]	[0.165]		[-0.078]
Intervention(t)	-0.017**	-0.012**	-0.018**	-0.009	-0.02**	-0.007**	-0.014***		-0.017***
	[-2.306]	[-2.005]	[-2.55]	[-1.119]	[-2.526]	[-2.203]	[-2.67]		[-3.042]
Intervention(t+1)	-0.026***	-0.002	-0.011*	-0.012*	-0.013*	-0.005	-0.002		-0.006
	[-4.098]	[-0.481]	[-1.812]	[-1.712]	[-1.853]	[-0.915]	[-0.426]		[-1.362]
Rating home	0	-0.002	0.002	0.004*	0	0.003*	0		0.003*
	[-0.139]	[-1.109]	[1.133]	[1.689]	[0.14]	[1.831]	[0.021]		[1.909]
Rating foreign	-0.028*	0.004	-0.049***	0	0.003	-0.002	-0.005		-0.002
	[-1.721]	[0.841]	[-4.734]	[-0.013]	[1.332]	[-1.052]	[-0.665]		[-0.934]
Outlook home	-0.007	0	-0.007	-0.005	0	-0.005	0.001		-0.012***
	[-1.325]	[-0.057]	[-1.274]	[-0.781]	[-0.013]	[-1.073]	[0.197]		[-3.286]
Outlook foreign	-0.001	-0.006	0	0.006	0.003	0	0.002		0.001
	[-0.056]	[-0.905]	[-0.033]	[0.499]	[0.592]	[0.083]	[0.263]		[0.304]
c1	0***	0	0*	0***	0***	0**	0***		0
	[3]	[0.916]	[1.911]	[5.93]	[13.247]	[2.489]	[8.709]		[1.568]
A	0	0	0	0	0	0	0.005**		0.018
	[0.002]	[0.006]	[0]	[0.001]	[0]	[0.002]	[1.999]		[1.321]
B	0.905***	0.927***	0.948***	0.925***	0.999***	0.937***	0.977***		0.883***
	[31.16]	[11.258]	[34.604]	[55.661]	[12540.785]	[34.697]	[464.698]		[12.511]

Panel E	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Spain									
c0	0.35***	0.58***	0.49***	0.49***	0.533***	0.66***	0.62***	0.65***	
	[18.56]	[39.04]	[46.38]	[30.58]	[42.011]	[55.37]	[43.69]	[57.18]	
ar1	0.99***	0.98***	0.97***	0.97***	0.946***	0.97***	0.98***	0.97***	
	[178.1]	[146.02]	[161.89]	[133.49]	[78.428]	[135.57]	[147.11]	[127.41]	
vix	0	0	0	0	0	0	0	0	
	[-1.16]	[-0.96]	[-0.11]	[-0.33]	[-1.423]	[-0.87]	[-0.84]	[-0.98]	
Intervention(t-1)	0	0	0.02**	0	0.043***	0	0	0	
	[0.32]	[0.32]	[2.46]	[0.12]	[5.238]	[-0.1]	[0.56]	[1.05]	
Intervention(t)	-0.01	-0.01**	-0.02***	-0.02**	-0.019**	0	-0.01**	-0.01**	
	[-1.37]	[-2.14]	[-3.22]	[-2.75]	[-2.038]	[-0.91]	[-2.2]	[-2.1]	
Intervention(t+1)	-0.04***	0	0.01*	-0.01*	-0.009	0	0	0	
	[-6.33]	[0.52]	[1.74]	[-1.84]	[-1.052]	[0.81]	[-0.91]	[0.54]	
Rating home	0*	0	0	0	0	0	0	0	
	[-1.95]	[0.27]	[-0.71]	[-0.93]	[0.076]	[-0.91]	[-1.04]	[-0.25]	
Rating foreign	-0.01	0	-0.01	0	-0.001	0	0	0	
	[-0.95]	[0.38]	[-0.96]	[-0.27]	[-0.239]	[0.34]	[0.82]	[-1.41]	
Outlook home	0.02***	0	0.01***	0	-0.004	0	0	0	
	[2.97]	[0.87]	[3.21]	[0.31]	[-0.561]	[-0.09]	[0.08]	[0.46]	
Outlook foreign	0	0	0	0.01	0.003	0	0	0	
	[-0.26]	[0]	[0.37]	[0.96]	[0.331]	[0.21]	[-1.08]	[0.09]	
c1	0***	0***	0***	0***	0***	0***	0	0***	
	[4.37]	[2.83]	[8.34]	[3.02]	[2.694]	[6.14]	[0.6]	[5.9]	
A	0.11**	0	0.67***	0	0	0	0	0	
	[2.33]	[0.52]	[4.5]	[0]	[0]	[0]	[0]	[0]	
B	0.65***	0.97***	0.24***	0.95***	0.955***	0.93***	0.94***	0.96***	
	[8.3]	[86.89]	[3.6]	[60.35]	[58.331]	[544.37]	[9.11]	[202.51]	

The estimation results are based on Eq (30) and (31), the mean and variance equations of the DCC of pairwise countries. The t-statistics are in parentheses. Significant level denoted as ***=p<0.01, **=p<0.05, *=p<0.1.

Table 33 ARCH-LM test

ARCH lag	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Greece									
1	676.49***	660.93***	643.13***	641.43***		665.86***	645.69***	686.55***	646.04***
2	675.57***	660.14***	642.26***	640.56***		665***	644.81***	685.61***	645.34***
4	673.85***	658.73***	640.89***	639.19***		663.27***	643.76***	683.89***	644.23***
8	671.38***	655.25***	637.7***	636.05***		660.48***	640.65***	680.66***	640.78***
10	673.11***	653.9***	635.96***	635.3***		658.82***	638.82***	679.93***	641.4***
12	670.15***	651.9***	634.31***	633.82***		656.99***	637.03***	678.03***	638.5***
Ireland									
1	950.54***	940.01***	933.91***	930.31***	665.86***		934.54***	943.5***	927.24***
2	949.6***	939.07***	933.14***	929.37***	665***		933.59***	942.55***	926.3***
4	947.85***	937.25***	931.62***	927.61***	663.27***		931.78***	940.67***	924.56***
8	944.76***	933.86***	928.62***	924.51***	660.48***		928.61***	937.47***	920.84***
10	943.03***	931.97***	926.77***	922.78***	658.82***		926.65***	935.68***	919***
12	940.99***	931.14***	925.34***	921.03***	656.99***		924.92***	933.88***	917.27***
Italy									
1	956.79***	949.19***	919.82***	933.18***	645.69***	934.54***		951.19***	942.3***
2	955.84***	948.23***	918.89***	932.24***	644.81***	933.59***		950.24***	941.37***
4	953.97***	946.44***	917.12***	930.82***	643.76***	931.78***		948.32***	939.53***
8	951.08***	942.83***	914.36***	927.92***	640.65***	928.61***		946.55***	937.56***
10	949.11***	940.99***	912.39***	925.87***	638.82***	926.65***		944.66***	935.74***
12	947.14***	939.03***	910.45***	923.91***	637.03***	924.92***		942.85***	933.88***
Portugal									
1	948.44***	955.42***	945.59***	942.2***	686.55***	943.5***	951.19***		956.82***
2	947.49***	954.54***	944.78***	941.25***	685.61***	942.55***	950.24***		955.89***
4	945.6***	952.68***	943.03***	939.41***	683.89***	940.67***	948.32***		953.99***
8	943.91***	949.77***	942.08***	937.98***	680.66***	937.47***	946.55***		950.72***
10	942.19***	947.9***	940.18***	936.08***	679.93***	935.68***	944.66***		949.31***
12	940.39***	946.13***	938.32***	934.24***	678.03***	933.88***	942.85***		947.29***
Spain									
1	953.51***	952.77***	926.91***	933.2***	646.04***	927.24***	942.3***	956.82***	
2	952.54***	951.81***	926.02***	932.32***	645.34***	926.3***	941.37***	955.89***	
4	950.7***	949.92***	924.23***	930.85***	644.23***	924.56***	939.53***	953.99***	
8	947.01***	946.16***	921***	927.39***	640.78***	920.84***	937.56***	950.72***	
10	946.49***	944.37***	919.09***	926.05***	641.4***	919***	935.74***	949.31***	
12	944.53***	942.47***	917.34***	924.29***	638.5***	917.27***	933.88***	947.29***	

This table shows the ARCH-LM test statistic for examining the null hypothesis of no ARCH effect. Results of different lag length are shown (1, 2, 4, 8, 10, 12) to see if the conclusion reached changes for different values. If the null hypothesis is rejected, there is ARCH effect in the rho. The results show that all pairwise correlations have consistent ARCH at the 1% level of significance. Significance level denoted as ***=p<0.01, **=p<0.05, *=p<0.1

Table 34 ARMA specification

ARMA(,)	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Greece									
(1,0)	**-3457.5**	**-3456.4**	**-3271**	**-3327**		**-3490.4**	**-3548.6**	**-3691**	**-3419.73**
(0,1)	-2253.75	-2446.96	-2425.81	-2470.11		-2444.65	-2671.63	-2353.7	-2556.05
(1,1)	-3455.6	-3454.73	-3268.97	-3325.28		-3452.51	-3546.64	-3446.96	-3419
(2,0)	-3455.6	-3454.72	-3268.97	-3325.26		-3452.48	-3546.64	-3654.73	-3418.87
(0,2)	-2681.35	-2826.63	-2763.11	-2814.24		-3450.76	-3007.66	-3654.72	-2784.9
(2,1)	-3453.68	-3452.51	-3267.17	-3323.9		-3267.17	-3545.84	-2226.63	-3418.57
(1,2)	-3453.02	-3452.48	-3266.99	-3323.8		-3266.99	-3545.78	-3652.51	-3417.17
(2,2)	-3451.6	-3450.76	-3265.38	-3321.96		-3268.97	-3545.41	-3552.48	-3416.54
Ireland									
(1,0)	**-4956.8**	**-5226.1**	**-4955.53**	**-4848.9**	**-3490.4**		**-5469.2**	**-5216.2**	**-5438.7**
(0,1)	-2689.83	-3240.44	-3186.62	-3014.9	-2444.65		-3617.1	-3236.38	-3711.95
(1,1)	-4954.99	-5224.16	-4948.94	-4846.91	-3452.51		-5467.9	-5215.4	-5436.93
(2,0)	-4955.01	-5224.16	-4948.09	-4846.91	-3452.48		-5467.87	-5215.36	-5436.9
(0,2)	-3409.66	-3909.42	-3799.15	-3628.63	-3450.76		-4250.45	-3893.81	-4303.24
(2,1)	-4954.21	-5222.3	-4954.1	-4847.89	-3267.17		-5466.22	-5213.37	-5436.76
(1,2)	-4954.59	-5223.01	-4950.65	-4846.12	-3266.99		-5466.55	-5213.7	-5437.25
(2,2)	-4953.24	-5221.94	-4944.93	-4843.03	-3268.97		-5464.35	-5212.56	-5435
Italy									
(1,0)	**-4848.7**	**-5792.6**	**-5009.1**	**-5064.3**	**-3548.6**	**-5469.2**		**-5527.4**	**-6562.1**
(0,1)	-2348.73	-3645.18	-3433.63	-3237.8	-2671.63	-3617.1		-3317.95	-4622.19
(1,1)	-4846.87	-5790.37	-5007.6	-5062.3	-3546.64	-5467.9		-5525.51	-6561.32
(2,0)	-4846.88	-5790.45	-5007.59	-5062.33	-3546.64	-5467.87		-5525.51	-6561.27
(0,2)	-3124.34	-4374.58	-3981.88	-3824.52	-3007.66	-4250.45		-4039.99	-5268.07
(2,1)	-4844.65	-5788.79	-5006.3	-5060.28	-3545.84	-5466.22		-5523.57	-6560.58
(1,2)	-4846.47	-5788.99	-5005.63	-5060.54	-3545.78	-5466.55		-5523.54	-6559.66
(2,2)	-4846.39	-5786.98	-5004.32	-5059.66	-3545.41	-5464.35		-5521.59	-6558.78
Portugal									
(1,0)	**-4824.7**	**-5248.47**	**-4930.9**	**-4718.9**	**-3691**	**-5216.2**	**-5527.4**		**-5491.1**
(0,1)	-2624.34	-2952.78	-2765.22	-2677.01	-2353.7	-3236.38	-3317.95		-3156.87
(1,1)	-4822.75	-5248.45	-4929.45	-4717.09	-3446.96	-5215.4	-5525.51		-5490.77
(2,0)	-4822.75	-5248.37	-4929.47	-4717.09	-3654.73	-5215.36	-5525.51		-5490.75
(0,2)	-3335.39	-3675.22	-3458.76	-3355.95	-3654.72	-3893.81	-4039.99		-3938.3
(2,1)	-4821.3	-5247.71	-4927.5	-4714.97	-2226.63	-5213.37	-5523.57		-5487.11
(1,2)	-4821.35	-5247.94	-4927.77	-4715.1	-3652.51	-5213.7	-5523.54		-5488.79
(2,2)	-4819.35	-5245.77	-4925.48	-4713.17	-3552.48	-5212.56	-5521.59		-5487.55

Table 34 *(continued)*

Spain								
(1,0)	**-4958.2**	**-5754.4**	**-5010.25**	**-5068.7**	**-3419.73**	**-5438.7**	**-6562.1**	**-5491.1**
(0,1)	-2594.06	-3570.38	-3377.67	-3249.35	-2556.05	-3711.95	-4622.19	-3156.87
(1,1)	-4956.46	-5752.65	-5010.03	-5067.7	-3419	-5436.93	-6561.32	-5490.77
(2,0)	-4956.48	-5752.71	-5009.93	-5067.75	-3418.87	-5436.9	-6561.27	-5490.75
(0,2)	-3320.75	-4285.6	-3933.57	-3830.97	-2784.9	-4303.24	-5268.07	-3938.3
(2,1)	-4954.3	-5753.42	-5012.26	-5067.38	-3418.57	-5436.76	-6560.58	-5487.11
(1,2)	-4954.97	-5751.2	-5009.02	-5066.39	-3417.17	-5437.25	-6559.66	-5488.79
(2,2)	-4953.26	-5751.44	-5010.04	-5065.38	-3416.54	-5435	-6558.78	-5487.55

The specification of the correlation equation, Eq (30), is identified by fitting an ARMA(m,n) model, while the lag-length selection is identified via AIC. The model is estimated for up to ARMA(2,2) for each country. The lag with the smallest AIC is chosen and highlighted in bold.

5.5 Conclusion

The pairwise conditional correlations between variance in sovereign CDS spreads in the Eurozone were higher during the sovereign debt crisis. The instability observed on sovereign CDS spreads of one country is in part due to volatility in another market (volatility spillover), especially surrounding policy intervention date. This has two important implications from the perspective of international investors. First, a high level of correlation will diminish the effect of portfolio diversification, as credit products for different Eurozone countries will all be subject to similar risks. Second, a higher volatility of correlation suggests that the reliability of correlation is weaker, creating doubts over portfolio strategies that are based on estimated correlation and covariance coefficients.

This study looks into the time-varying correlation coefficients and tries to capture the impact of the policy interventions. It analyses correlations between 9 EMU countries – Austria, Belgium, France, Germany, Greece, Ireland, Italy, Portugal and Spain – during the Eurozone sovereign debt crisis, using a dynamic conditional correlation GARCH (DCC-GARCH) model. It also investigates how policy interventions influenced the conditional correlations between these EMU nations.

First, we find correlations between CDS spread variances are dynamic and time-varying for all the sample countries. Comparing the pairwise series, there was a significant pattern for all the bilateral relations, although not all of the interventions have exactly the same influence. Most of the policy interventions led to a significant increase in pairwise correlations. This temporary reaction, with a reversion to the normal range, is suggested to be an intervention-caused contagion effect. Comparing across countries, correlations with Austria and Germany are less volatile and show weaker reactions to these interventions. One interpretation is that this reflects "two-way feedback" between the healthy country and the bailed-out country, as proposed by Acharya et al. (2011), causing public-to-public risk transfer. The increased debt and deficit partly result from assisting other troubled nations. Through policy interventions, any deterioration in the sovereign creditworthiness of the healthy countries could be transmitted to the bailed-out countries.

With respect to the impact of policy intervention, our empirical analysis suggests that announcements of policy interventions have a significant and consistent impact on pairwise cross-market correlations. The negative sign of policy intervention indicates a negative impact on cross-market correlations, which could be interpreted as that these policy interventions are successful in relieving the financial stress in the EMU by lowering the inter-linkages between markets. In addition, interventions at t-1 and t+1 are included in the regression to account for differences in market opening times and different reactions speed to interventions news. They demonstrate less significant but still strong impacts on most of the pairwise DCC, which are positive in some cases, especially for intervention at t-1. One possible reason for the different sign on the correlation coefficient is the different speed in reacting to announcements (Chiang et al. 2007). Policy interventions have in general been found to be a source of market uncertainty. Nevertheless, credit rating/outlook and VIX do not show much impact on the dynamic conditional correlation between the variances of EMU countries. This result suggests that policy interventions played a direct and significant role in shaping the structure of dynamic correlations in the EMU markets.

The results of the analysis of the correlation between variances have various implications. For portfolio management, an investor seeking to optimize his CDS portfolio or portfolio containing credit risk of the 9 EMU nations may produce more accurate estimates by taking account of dynamic correlation. The investor may even predict the direction of CDS co-movements using past values. Indeed, failing to account for the impact of policy interventions on the correlation will result in an over-diversified and sub-optimal portfolio.

For contagion analysis, following Forbes and Rigobon (2002), financial contagion is defined as a significant increase in cross-market correlation/covariance during a period of turmoil. It is related to investor sentiment, and by definition goes beyond any explanation based on links between the fundamentals applying to each country. From this perspective, interventions in one particular market give a strong signal for investors in related countries. The announcements of bailout packages on each country in financial stress and the news regarding the regional rescue fund were paid close attention. Therefore, information specific to one market is likely to be used in other markets, causing a spillover effect. This was especially evident after we controlled for international influence (the US VIX), and both domestic and foreign sovereign credit rating and outlook.

CHAPTER 6

Conclusion and future work

6.1 Conclusion

This thesis has presented a study that examined pairwise correlations between means and variances in sovereign credit markets; in particular, it sought evidence of contagion effects, by focusing on parallel movements between markets in the wake of the recent financial crisis (using a narrow definition of contagion). Furthermore, it tested whether policy interventions had any effect on the dynamics of these correlations.

We first looked at the correlation between means, starting with the interactions between credit ratings of 37 sovereign states and their CDS spreads during and after the recent global financial crisis. With these results, we were able to examine the sovereign CDS spreads interdependence/correlation of 10 EU members during Eurozone debt crisis, while controlling for the rating and other external influences affecting sovereign CDS spreads. The models employed were mainly the cointegration approach, including VECM, Granger causality and impulse response.

We then looked at the correlation between variances. This part of the study investigated the dynamic correlation between 9 major EMU countries' CDS markets during the sovereign debt crisis, and examined the impacts of policy interventions on these markets, using the DCC-GARCH model. Specifically, the main purpose was to assess to what extent the bailout plans influenced the dynamics of these correlations in sovereign CDS markets, after controlling for international influence (US VIX) and sovereign credit ratings in both domestic and foreign countries.

We found, first, a significant response of government CDS spreads to both rating and outlook, with a stable long-run equilibrium relationship between sovereign CDS spreads and rating/outlook for the majority of countries. Credit rating and outlook led sovereign CDS spreads in most cases. Second, we found negative international spillover effects of outlook changes on CDS markets, but no similar influence from rating changes. Moreover, the initial credit quality of a country did not have much influence on its spillover effects. Furthermore, the results underline that spillover is a regional effect rather than a global effect, because countries within the same region share more linkages. Nevertheless, the US market does have a universal global influence, but it is unique in this respect. Finally, sovereign CDS spreads become more sensitive to external factors during times of crisis, while these same external factors have much weaker influence on spillover in pre-crisis periods. International investors tend to be more sensitive to recent developments in the global environment, while expectations and confidence are crucial during times of turmoil.

With respect to the EU sovereign CDS interdependence, we found that, firstly, before a policy intervention (bailout), the changes in the CDS spreads of bailed-out countries had a strong influence on core European countries, while the spillover in the opposite direction was much weaker. This leads to the argument that the credit risk spillover channel was from the PIIGS to the core countries before intervention. Secondly, bailout plans exposed the core countries to the credit risk of the bailed-out countries (Ireland, Portugal and Spain); changes in PIIGS spreads were able to trigger larger shifts in those for core countries. Austria, Belgium, France and

Germany were strongly affected, while the UK, the only non-Eurozone member in our sample, was less influenced. Moreover, the influences of bailout countries differed from each other. Thirdly, we found that the core countries (especially Austria and Germany) gained extra influence on the bailed-out countries after the intervention, as they participated in the financial aid as credit guarantees for the PIIGS. It is argued that this led to a greater reliance of the bailed-out countries on the core countries; there is also the possibility that the core countries will be more sensitive to difficulties with their own national debt. The results indicate the existence of credit risk contagion. Finally, the spillover of credit risk is consistently found across countries and rescue plans after intervention, but its precise nature depends on the country-specific characteristics at that time. We suggest that the influence of a country depends on its "information", while the vulnerability of country depends on its "fiscal situation", corresponding to the two transmission channels discussed in the literature chapter[38]. Although financing the bailout makes the core countries more exposed to the PIIGS, countries with solid fiscal fundamentals (high Debt-GDP and Deficit-GDP ratio) should be less sensitive to external shocks, like Austria and Germany. In contrast, countries with more "information" (like expectation of future bailout) are more likely to affect other nations. The CDS spreads of one country will be less informative for investors if it has just experienced a rescue plan.

In the second empirical chapter, we found that the correlations between CDS spread variances are dynamic and time-varying for all the sample countries. There was a significant pattern for all the bilateral relations. Most of the policy interventions led to a significant increase in the pairwise correlations. The temporary reaction, with a

[38] Misso and Watzka (2011) have similar findings that Greece could influence investor sentiment regarding other economically problematic or politically unstable countries, but that such contagion does not hit essentially stable countries.

reversion to the normal range, is suggested to be an intervention-caused contagion effect. Comparing across countries, correlations with Austria and Germany are less volatile and show a weaker reaction to these interventions. One interpretation is that a “two-way feedback” between the healthy country and the bailed-out country, as proposed by Acharya et al. (2011), causes a public-to-public risk transfer. The increased debt and deficit partly result from assisting other troubled nations. Through policy interventions, any deterioration in the sovereign creditworthiness of the healthy countries could transmit back to the bailed-out countries. To examine the impact of policy intervention, our empirical analysis controlled for the external regressors, including VIX and credit rating and outlook. The estimation result suggests that credit rating/outlook and VIX do not have much impact on the dynamic conditional correlation between the variances of EMU countries, while announcements of a policy intervention have a significant and consistent impact on pairwise cross-market correlations. This finding suggests that policy interventions play the most direct and significant role in shaping the structure of dynamic correlations in the EMU markets.

6.2 Implications

The high level of pairwise correlations between mean and variances has two significant implications for international investors. First, they diminish the effectiveness of portfolio diversification, as credit products for different Eurozone countries will all be subject to similar risks. Second, the higher volatility of these correlations undermines the reliability of correlation and covariance, which in turn creates doubts over any portfolio strategies based on estimated correlation and covariance coefficients. Moreover, the time-varying correlation and covariance coefficients produce evidence of contagion effects, especially surrounding policy interventions. This study shows a comprehensive picture of international contagion, across national borders and asset classes, during the recent financial crisis.

International investors would be rightly worried about greater links between asset prices across national boundaries and asset classes. If cross-country and cross-market correlation and covariance increase during a crisis period, portfolio diversification is likely to fail to deliver safety. The diversification strategies for portfolio management are unable to diversify risk, leaving a portfolio exposed to international shock. Failing to account for the impact of policy intervention on the correlation would result in an over-diversified and sub-optimal portfolio. Our results confirm such worries about international integration. Nevertheless, our study also provides an incentive, in that the contagion we found was regional rather than global. An investor seeking to optimize his CDS portfolio or portfolio containing credit risk of the EU nations may produce more accurate estimates by taking into account the dynamic correlation. In a period of crisis, further portfolio diversification across international markets could help limit potential credit risk spillover. On the other hand, for a speculator, it could create profit margins if they understand the direction and channels of information transmission. For an arbitrager, the difference and the lead-lag relation between credit derivate markets can be found more precisely.

For policy makers, at the country level, of the two factors affecting contagion, perhaps the more crucial is economic and political stability. It reflects the fact that co-movements are unavoidable without reform at country level. To reduce the scope for financial contagion, it will be necessary to reduce the fiscal and current account deficit, to enhance the quality of the financial sector. Without resolving the financial stress, either by improving the fundamentals or by receiving a rescue fund, it will not be possible to keep the sovereign credit market stable.

At the EU policy level, the approval of policies, like bailouts, should, amongst other considerations, be related to the identification of contagion effects. Interventions in one particular market can be a strong signal for investors in similar countries. Therefore, information specific to one market is likely to be used in other markets, causing a spillover effect, especially after other international influences are controlled for. This might explain why interventions are associated with higher degrees of correlation between EMU nations.

The euro was introduced to provide a strong currency across financial markets and to avoid devaluations. The stability pact forces each government to remain within the deficit limit, 6%, and debt limit, 60%. However, there is no supranational form of government to control tax, spending and transfer between poor and rich members. Although different countries fell into crisis for different reasons, excessive credit creation was a common factor that needs to be taken account of by regulators and policy makers. The crisis resolution mechanism (the ESM) provides a precious lesson for the EU, and may serve as evidence that a Eurobond will be needed to solve the debt issue permanently. The ECB faces constitutional and political obstacles, and, for instance, has been unable to act like the Bank of England, which has used QE to facilitate its purchase of government debt. The ECB has nonetheless done a considerable part in avoiding an even worse crisis by adopting series of "unconventional measures". Setting up a permanent firewall to protect its members from future crisis should be on its task list.

6.3 Future research

There are several limitations to the present study, and these could be addressed by further research. First, we did not examine the potential determinants of the correlations between the sovereign CDS spreads. This is a fast-growing topic in the area, and helps in understanding the mechanisms underlying the Eurozone debt crisis. Such data would be especially meaningful to economists and policy makers. Second, in terms of the relation between CDS and rating, our sample covers only the period 2004–12, and some major countries are not included in the sample, in particular the US and Germany, because they did not experience any credit rating changes in the sample period. Extending both the sample period and the countries could help shape a better story and more convincing results. Third, various policy interventions were announced during the Eurozone debt crisis, but the present study essentially considered the impact only of bailouts (in the correlation between means) and the establishment of the rescue funds, the EFSF and the ESM (in the correlation between variances). It would be of interest to study other rescue plans, which would also help resolve the potential contamination problem of different interventions. The statistical and econometric frameworks might be improved so as to eliminate the cross-influences of various other supporting measures, to aid the identification of their economic and financial implications.

References

ACHARYA, V. V., DRECHSLER, I. & SCHNABL, P. 2011a. A pyrrhic victory-bank bailouts and sovereign credit risk. National Bureau of Economic Research.

ACHARYA, V. V., SHIN, H. S. & YORULMAZER, T. 2011b. Crisis resolution and bank liquidity. *Review of Financial Studies,* 24**,** 2166-2205.

ACHARYA, V. V. & YORULMAZER, T. 2008. Cash-in-the-market pricing and optimal resolution of bank failures. *Review of Financial Studies,* 21**,** 2705-2742.

AFONSO, A., FURCERI, D. & GOMES, P. 2012. Sovereign credit ratings and financial markets linkages: Application to European data. *Journal of International Money and Finance,* 31**,** 606-638.

AFONSO, A., GOMES, P. M. & ROTHER, P. 2007. What'Hides' Behind Sovereign Debt Ratings?

AGHION, P., BOLTON, P. & FRIES, S. 1999. Optimal design of bank bailouts: the case of transition economies. *Journal of Institutional and Theoretical Economics (JITE)/Zeitschrift für die gesamte Staatswissenschaft***,** 51-70.

AIZENMAN, J., HUTCHISON, M. & JINJARAK, Y. 2013. What is the risk of European sovereign debt defaults? Fiscal space, CDS spreads and market pricing of risk. *Journal of International Money and Finance,* 34**,** 37-59.

AKTUG, R. E., VASCONCELLOS, GERALDO M. AND BAE, YOUNGSOO, 2013. The Dynamics of Sovereign Credit Default Swap and Bond Markets: Empirical Evidence from the 2001-2007 Period. *Applied Economics Letters*.

ALLEN, F. & GALE, D. 2000. Financial contagion. *Journal of political economy,* 108**,** 1-33.

ALSAKKA, R. & AP GWILYM, O. 2009. Heterogeneity of sovereign rating migrations in emerging countries. *Emerging Markets Review,* 10**,** 151-165.

ALSAKKA, R. & AP GWILYM, O. 2010. Leads and lags in sovereign credit ratings. *Journal of Banking & Finance,* 34**,** 2614-2626.

ALSAKKA, R. & AP GWILYM, O. 2012. Foreign exchange market reactions to sovereign credit news. *Journal of International Money and Finance,* 31**,** 845-864.

ALTER, A. & BEYER, A. 2014. The dynamics of spillover effects during the European sovereign debt turmoil. *Journal of Banking & Finance,* 42**,** 134-153.

ALTER, A. & SCHULER, Y. S. 2012. Credit spread interdependencies of European states and banks during the financial crisis. *Journal of Banking & Finance,* 36**,** 3444-3468.

AMATO, J. D. 2005. Risk aversion and risk premia in the CDS market. *BIS Quarterly Review,* 12**,** 55-68.

AMMER, J. & CAI, F. 2011. Sovereign CDS and bond pricing dynamics in emerging markets: Does the cheapest-to-deliver option matter? *Journal of International Financial Markets, Institutions and Money,* 21**,** 369-387.

ANDERSEN, T. G., BOLLERSLEV, T., DIEBOLD, F. X. & LABYS, P. 2001. The distribution of realized exchange rate volatility. *Journal of the American statistical association,* 96**,** 42-55.

ANG, A. & LONGSTAFF, F. A. 2013. Systemic sovereign credit risk: Lessons from the us and europe. *Journal of Monetary Economics*.

ARELLANO, C. & BAI, Y. 2012. Linkages across Sovereign Debt Markets. *Manuscript, University of Rochester*.

ARELLANO, C., CONESA, J. C. & KEHOE, T. J. 2012. Chronic sovereign debt crises in the Eurozone, 2010-2012. *Federal Reserve Bank of Minneapolis Policy Paper***,** 12-4.

AREZKI, R., CANDELON, B. & SY, A. 2011. Sovereign rating news and financial markets spillovers: Evidence from the European debt crisis. *IMF working papers***,** 1-27.

ATTINASI, M. G., CHECHERITA, C. & NICKEL, C. 2009. What explains the surge in euro area sovereign spreads during the financial crisis of 2007-09?

BAI, J. & WEI, S.-J. 2012. When is there a strong transfer risk from the sovereigns to the corporates? Property rights gaps and CDS spreads. National Bureau of Economic Research.

BEETSMA, R. & UHLIG, H. 1999. An analysis of the Stability and Growth Pact. *The Economic Journal,* 109**,** 546-571.

BEINE, M. 2004. Conditional covariances and direct central bank interventions in the foreign exchange markets. *Journal of Banking & Finance*, 28**,** 1385-1411.
BEIRNE, J. & FRATZSCHER, M. 2013. The pricing of sovereign risk and contagion during the European sovereign debt crisis. *Journal of International Money and Finance,* 34**,** 60-82.
BENSAFTA, K. M. & SEMEDO, G. 2013. Market Volatility Transmission and Central banking: what happened during subprime crisis? *Working paper*.
BILLIO, M. & PELIZZON, L. 2003. Contagion and interdependence in stock markets: Have they been misdiagnosed? *Journal of Economics and Business,* 55**,** 405-426.
BLANCO, R., BRENNAN, S. & MARSH, I. W. 2005. An empirical analysis of the dynamic relation between investment-grade bonds and credit default swaps. *Journal of Finance,* 60**,** 2255-2281.
BOLLERSLEV, T. 1990. Modelling the Coherence in Short-run Nominal Exchange Rates: A Multivariate Generalized ARCH Model. *The Review of Economics and Statistics,* 72.
BOLLERSLEV, T., ENGLE, R. F. & WOOLDRIDGE, J. M. 1988. A Capital Asset Pricing Model with Time-Varying Covariances. *Journal of Political Economy,* 96**,** 116-31.
BRONER, F. & VENTURA, J. 2011. Globalization and risk sharing. *The Review of Economic Studies,* 78**,** 49-82.
BROOKS, R., FAFF, R. W., HILLIER, D. & HILLIER, J. 2004. The national market impact of sovereign rating changes. *Journal of Banking & Finance,* 28**,** 233-250.
BROWN, C. O. & DINC, I. S. 2011. Too many to fail? Evidence of regulatory forbearance when the banking sector is weak. *Review of Financial Studies,* 24**,** 1378-1405.
BUITER, W., CORSETTI, G., ROUBINI, N., REPULLO, R. & FRANKEL, J. 1993. Excessive deficits: Sense and nonsense in the Treaty of Maastricht. *Economic Policy***,** 58-100.
BURNSIDE, C. & EICHENBAUM, M. 2001. Prospective Deficits and the Asian Currency Crisis. *Journal of Political Economy,* 109.
CACERES, C., GUZZO, V. & SEGOVIANO BASURTO, M. 2010. Sovereign spreads: Global risk aversion, contagion or fundamentals? *IMF working papers***,** 1-29.
CANTOR, R. & PACKER, F. 1996. Determinants and impact of sovereign credit ratings. *Economic Policy Review,* 2.
CAPORIN, M., PELIZZON, L., RAVAZZOLO, F. & RIGOBON, R. 2013. Measuring sovereign contagion in Europe. National Bureau of Economic Research.
CECCHETTI, S. G., MOHANTY, M. S. & ZAMPOLLI, F. 2010. *The future of public debt: prospects and implications,* Bank for International Settlements, Monetary and Economic Department.
CHAN-LAU, J. A. & KIM, Y. S. 2004. *Equity prices, credit default swaps, and bond spreads in emerging markets,* International Monetary Fund.
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.
CHRISTOPHER, R., KIM, S. J. & WU, E. 2012. Do sovereign credit ratings influence regional stock and bond market interdependencies in emerging countries? *Journal of International Financial Markets Institutions & Money,* 22**,** 1070-1089.
CLAEYS, P. & VAŠ ČEK, B. 2012. Measuring sovereign bond spillover in Europe and the impact of rating news.
CLAEYS, P. & VAŠ ČEK, B. 2014. Measuring Bilateral Spillover and Testing Contagion on Sovereign Bond Markets in Europe. *Journal of Banking & Finance*.
COCHRANE, J. H. 2010. Greek Myths and the Euro Tragedy. *The Wall Street Journal,* 18.
COLE, H. L. & KEHOE, T. J. 1996. A self-fulfilling model of Mexico's 1994–1995 debt crisis. *Journal of international Economics,* 41**,** 309-330.
COLE, H. L. & KEHOE, T. J. 2000. Self-fulfilling debt crises. *The Review of Economic Studies,* 67**,** 91-116.
CONESA, J. C. & KEHOE, T. J. 2012. Gambling for redemption and self-fulfilling debt crises. Federal Reserve Bank of Minneapolis.
CONST NCIO, V. 2012. Contagion and the European debt crisis. *Financial Stability Review,* 16**,** 109-121.
CORSETTI, G., PERICOLI, M. & SBRACIA, M. 2011. Correlation Analysis of Financial Contagion. *Financial Contagion.* John Wiley & Sons, Inc.
CORSETTI, G., PESENTI, P., ROUBINI, N. & TILLE, C. 2000. Competitive devaluations: toward a welfare-based approach. *Journal of International Economics,* 51**,** 217-241.
DE SANTIS, R. 2012. The euro area sovereign debt crisis: Safe haven, credit rating agencies and the spread of the fever from Greece, Ireland and Portugal.

DELATTE, A.-L., GEX, M. & L PEZ-VILLAVICENCIO, A. 2012. Has the CDS market influenced the borrowing cost of European countries during the sovereign crisis? *Journal of International Money and Finance,* 31**,** 481-497.

DEMIRGUC-KUNT, A. & HUIZINGA, H. 2010. *Are Banks Too Big to Fail Or Too Big to Save?: International Evidence from Equity Prices and CDS Spreads,* Centre for Economic Policy Research.

DIAMOND, D. W. & RAJAN, R. G. 2002. Bank bailouts and aggregate liquidity. *The American Economic Review,* 92**,** 38-41.

DIAMOND, D. W. & RAJAN, R. G. 2005. Liquidity shortages and banking crises. *The Journal of Finance,* 60**,** 615-647.

DIECKMANN, S. & PLANK, T. 2012. Default risk of advanced economies: An empirical analysis of credit default swaps during the financial crisis. *Review of Finance,* 16**,** 903-934.

DORNBUSCH, R., PARK, Y. C. & CLAESSENS, S. 2000. Contagion: How it spreads and how it can be stopped. *World Bank Research Observer,* 15**,** 177-197.

DUFFIE, D., PEDERSEN, L. H. & SINGLETON, K. J. 2003. Modeling sovereign yield spreads: A case study of Russian debt. *Journal of Finance,* 58**,** 119-159.

EDWARDS, S. 1984. LDC's foreign borrowing and default risk: an empirical investigation. National Bureau of Economic Research Cambridge, Mass., USA.

EICHENGREEN, B., ROSE, A. K. & WYPLOSZ, C. 1996. Contagious currency crises. National bureau of economic research.

EJSING, J. & LEMKE, W. 2011. The Janus-headed salvation: Sovereign and bank credit risk premia during 2008–2009. *Economics Letters,* 110**,** 28-31.

ENDERS, W. 2004. *Applied Econometric Time Series,* Wiley.

ENGLE, R. 2002. Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models. *Journal of Business and Economic Statistics***,** 339-350.

ENGLE, R. F. 1982. Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica,* 50**,** 987-1007.

ENGLE, R. F. & KRONER, K. F. 1995. Multivariate Simultaneous Generalized ARCH. *Econometric Theory,* 11**,** 122-150.

ENGLE, R. F., NG, V. K. & ROTHSCHILD, M. 1990. Asset pricing with a factor-arch covariance structure: Empirical estimates for treasury bills. *Journal of Econometrics,* 45**,** 213-237.

ENGLE, R. F. & SHEPPARD, K. 2001. Theoretical and Empirical properties of Dynamic Conditional Correlation Multivariate GARCH. *National Bureau of Economic Research Working Paper Series,* No. 8554.

FAVERO, C. A. & GIAVAZZI, F. 2002. Is the international propagation of financial shocks non-linear? Evidence from the ERM. *Journal of International Economics,* 57**,** 231-246.

FELDSTEIN, M. 1998. The political economy of the European economic and monetary union: political sources of an economic liability. National Bureau of Economic Research.

FENDER, I., HAYO, B. & NEUENKIRCH, M. 2012. Daily pricing of emerging market sovereign CDS before and during the global financial crisis. *Journal of Banking & Finance,* 36**,** 2786-2794.

FERREIRA, M. A. & GAMA, P. M. 2007. Does sovereign debt ratings news spill over to international stock markets? *Journal of Banking & Finance,* 31**,** 3162-3182.

FONTANA, A. & SCHEICHER, M. 2010. An analysis of euro area sovereign CDS and their relation with government bonds. European Central Bank.

FORBES, K. J. & RIGOBON, R. 2002. No contagion, only interdependence: measuring stock market comovements. *The Journal of Finance,* 57**,** 2223-2261.

GALI, J. & MONACELLI, T. 2008. Optimal monetary and fiscal policy in a currency union. *Journal of international Economics,* 76**,** 116-132.

GANDE, A. & PARSLEY, D. C. 2005. News spillovers in the sovereign debt market. *Journal of Financial Economics,* 75**,** 691-734.

GENNAIOLI, N., MARTIN, A. & ROSSI, S. 2012. Sovereign default, domestic banks, and financial institutions. *Domestic Banks, and Financial Institutions (March 15, 2012)*.

GOLDSTEIN, M. A., KAMINSKY, G. L. & REINHART, C. 2000. *Assessing Financial Vulnerability: An Early Warning Signals for Emerging Markets,* Peterson Institute.

GONZALO, J. & GRANGER, C. 1995. Estimation of Common Long-Memory Components in Cointegrated Systems. *Journal of Business & Economic Statistics,* 13**,** 27-35.

GORTON, G. & HUANG, L. 2004. Liquidity, Efficiency, and Bank Bailouts. *The American Economic Review,* 94**,** 455-483.

GRAMMATIKOS, T. & VERMEULEN, R. 2012. Transmission of the financial and sovereign debt crises to the EMU: Stock prices, CDS spreads and exchange rates. *Journal of International Money and Finance,* 31**,** 517-533.
HASSENE, B. M. B. & KAIS, M. 2011. Contagion and transmission shocks of the volatility in the equity markets: The case of developed countries. *Interdisciplinary Journal of Research in Business,* 1.
HAUNER, D., JONAS, J. & KUMAR, M. S. 2010. Sovereign Risk: Are the EU's New Member States Different?*. *Oxford Bulletin of Economics and Statistics,* 72**,** 411-427.
HEINKE, V. G. 2006. Credit spread volatility, bond ratings and the risk reduction effect of watchlistings. *International Journal of Finance & Economics,* 11**,** 293-303.
HILL, P. & FAFF, R. 2010. The market impact of relative agency activity in the sovereign ratings market. *Journal of Business Finance & Accounting,* 37**,** 1309-1347.
HILSCHER, J. & NOSBUSCH, Y. 2010. Determinants of sovereign risk: Macroeconomic fundamentals and the pricing of sovereign debt*. *Review of Finance,* 14**,** 235-262.
HONG, Y. 2001. A test for volatility spillover with application to exchange rates. *Journal of Econometrics,* 103**,** 183-224.
HONOHAN, P. 2010. The Irish Banking Crisis Regulatory and Financial Stability Policy 2003-2008. *Report to the Irish Minister for Finance by the Governor of the Central Bank (Dublin)*.
HOOPER, V., HUME, T. & KIM, S.-J. 2008. Sovereign rating changes—Do they provide new information for stock markets? *Economic Systems,* 32**,** 142-166.
HOUWELING, P. & VORST, T. 2005. Pricing default swaps: Empirical evidence. *Journal of International Money and Finance,* 24**,** 1200-1225.
HULL, J., PREDESCU, M. & WHITE, A. 2004. The relationship between credit default swap spreads, bond yields, and credit rating announcements. *Journal of Banking & Finance,* 28**,** 2789-2811.
IMF 2010. Resolving the Crisis Legancy and meeting New Challenges to Financial Stability *IMF Global Financial Stability Report*.
ISMAILESCU, I. & KAZEMI, H. 2010. The reaction of emerging market credit default swap spreads to sovereign credit rating changes. *Journal of Banking & Finance,* 34**,** 2861-2873.
JOHANSEN, S. & JUSELIUS, K. 1994. Identification of the long-run and the short-run structure an application to the ISLM model. *Journal of Econometrics,* 63**,** 7-36.
JONES, C. M., LAMONT, O. & LUMSDAINE, R. L. 1998. Macroeconomic news and bond market volatility. *Journal of Financial Economics,* 47**,** 315-337.
JUSELIUS, K. 2006. *The cointegrated VAR model: methodology and applications,* Oxford University Press.
KALBASKA, A. & GATKOWSKI, M. 2012. Eurozone sovereign contagion: Evidence from the CDS market (2005-2010). *Journal of Economic Behavior & Organization,* 83**,** 657-673.
KAMINSKY, G. & SCHMUKLER, S. L. 2002. Emerging market instability: Do sovereign ratings affect country risk and stock returns? *World Bank Economic Review,* 16**,** 171-195.
KAMINSKY, G. L. & REINHART, C. 2000. On crises, contagion, and confusion. *Journal of International Economics,* 51**,** 145-168.
KAMINSKY, G. L. & REINHART, C. 2003. The center and the periphery: the globalization of financial turmoil.
KAMINSKY, G. L., REINHART, C. & VEGH, C. A. 2003. The unholy trinity of financial contagion. National Bureau of Economic Research.
KIM, S.-J. & WU, E. 2011. International Bnak Flows to Emerging Markets: Influence of Sovereign Credit Ratings and Their Regional Spillover Effects. *Journal of Financial Research,* 34**,** 331-364.
KING, M. A. & WADHWANI, S. 1990. Transmission of Volatility Between Stock Markets. *Review of Fiancial Studies,* 3**,** 5*33.
KODRES, L. E. & PRITSKER, M. 2002. A Rational Expectations Model of Financial Contagion. *The Journal of Finance,* 57**,** 769-799.
KOOP, G., PESARAN, M. H. & POTTER, S. M. 1996. Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics,* 74**,** 119-147.
KR USSL, R. 2005. Do credit rating agencies add to the dynamics of emerging market crises? *Journal of Financial Stability,* 1**,** 355-385.
LANE, P. R. 2006. The real effects of EMU. *Journal of Economic perspectives,* 20**,** 47-66.
LANE, P. R. 2011. The Irish Crisis. *CEPR Discussion Paper No. DP8287*.
LANE, P. R. 2012. The European sovereign debt crisis. *The Journal of Economic Perspectives,* 26**,** 49-67.

LI, H., JEON, B. N., CHO, S.-Y. & CHIANG, T. C. 2008. The impact of sovereign rating changes and financial contagion on stock market returns: Evidence from five Asian countries. *Global Finance Journal,* 19**,** 46-55.

LONGSTAFF, F. A., PAN, J., PEDERSEN, L. H. & SINGLETON, K. J. 2011. How Sovereign Is Sovereign Credit Risk? *American Economic Journal-Macroeconomics,* 3**,** 75-103.

MAILATH, G. J. & MESTER, L. J. 1994. A positive analysis of bank closure. *Journal of Financial Intermediation,* 3**,** 272-299.

METIU, N. 2012. Sovereign risk contagion in the Eurozone. *Economics Letters,* 117**,** 35-38.

MILESI‐FERRETTI, G. M. & TILLE, C. 2011. The great retrenchment: international capital flows during the global financial crisis. *Economic Policy,* 26**,** 289-346.

MIN, H.-G. & HWANG, Y.-S. 2012. Dynamic correlation analysis of US financial crisis and contagion: evidence from four OECD countries. *Applied Financial Economics,* 22**,** 2063-2074.

MINK, M. & DE HAAN, J. 2013. Contagion during the Greek sovereign debt crisis. *Journal of International Money and Finance,* 34**,** 102-113.

MISSIO, S. & WATZKA, S. 2011. Financial contagion and the European debt crisis. CESifo working paper: Monetary Policy and International Finance.

NORDEN, L. & WEBER, M. 2004. Informational efficiency of credit default swap and stock markets: The impact of credit rating announcements. *Journal of Banking & Finance,* 28**,** 2813-2843.

PACKER, F. & ZHU, H. 2005. Contractual terms and CDS pricing. *BIS Quarterly Review***,** 89.

PALLADINI, G. & PORTES, R. 2011. Sovereign CDS and bond pricing dynamics in the euro-area. National Bureau of Economic Research.

PAN, J. & SINGLETON, K. J. 2008a. Default and recovery implicit in the term structure of sovereign CDS spreads. *Journal of Finance,* 63**,** 2345-2384.

PAN, J. U. N. & SINGLETON, K. J. 2008b. Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads. *The Journal of Finance,* 63**,** 2345-2384.

PANAGEAS, S. 2010. Bailouts, the incentive to manage risk, and financial crises. *Journal of Financial Economics,* 95**,** 296-311.

PENATI, A. & PROTOPAPADAKIS, A. 1988. The effect of implicit deposit insurance on banks' portfolio choices with an application to international 'overexposure'. *Journal of Monetary Economics,* 21**,** 107-126.

PESARAN, H. H. & SHIN, Y. 1998. Generalized impulse response analysis in linear multivariate models. *Economics Letters,* 58**,** 17-29.

PRITSKER, M. 2001. The channels for financial contagion. *International financial contagion.* Springer.

REISEN, H. & VON MALTZAN, J. 1999. Boom and Bust and Sovereign Ratings. *International Finance,* 2**,** 273-293.

SACHS, J. D., TORNELL, A. & VELASCO, A. 1996. Financial Crises in Emerging Markets: The Lessons from 1995. *Brookings Papers on Economic Activity,* 27**,** 147-216.

SANDER, H. & KLEIMEIER, S. 2003. Contagion and causality: an empirical investigation of four Asian crisis episodes. *Journal of International Financial Markets, Institutions and Money,* 13**,** 171-186.

SGHERRI, S. & ZOLI, E. 2009. Euro area sovereign risk during the crisis. *IMF Working Papers***,** 1-23.

SILVENNOINEN, A. & TER SVIRTA, T. 2008. Multivariate GARCH models. *Working Paper Series in Economics and Finance*.

STEELEY, J. M. 2006. Volatility transmission between stock and bond markets. *Journal of International Financial Markets, Institutions and Money,* 16**,** 71-86.

SY, A. N. 2004. Rating the rating agencies: Anticipating currency crises or debt crises? *Journal of Banking & Finance,* 28**,** 2845-2867.

TREVINO, I. 2014. Channels of Financial Contagion: Theory and Experiments. *Working paper*.

TSE, Y. K. & TSUI, A. K. C. 2002. A Multivariate Generalized Autoregressive Conditional Heteroscedasticity Model with Time-Varying Correlations. *Journal of Business & Economic Statistics,* 20**,** 351-62.

VERONESI, P. & ZINGALES, L. 2010. Paulson's gift. *Journal of Financial Economics,* 97**,** 339-368.

VON HAGEN, J., SCHUKNECHT, L. & WOLSWIJK, G. 2011. Government bond risk premiums in the EU revisited: The impact of the financial crisis. *European Journal of Political Economy,* 27**,** 36-43.

WSJ. 2013. Greek Bailout Déjà Vu? *The Wall Street Journal*.

WYPLOSZ, C. 1997. EMU: Why and how it might happen. *The journal of economic perspectives,* 11**,** 3-21.

ZHU, H. 2006. An empirical comparison of credit spreads between the bond market and the credit default swap market. *Journal of Financial Services Research,* 29**,** 211-235.

Appendixes

Appendix 1

Table 35 S&P, Moody's and Fitch rating scales

	Rating				Outlook	
	S&P	Moody's	Fitch	Transfer	Notation	Transfer
Investment grade	AAA	Aaa	AAA	20	Positive	1
	AA+	Aa1	AA+	18	watch/RUR positive	0.5
	AA	Aa2	AA	18	stable	0
	AA-	Aa3	AA-	17	watch/RUR negative	-0.5
	A+	A1	A+	16	negative	-1
	A	A2	A	15		
	A-	A3	A-	14		
	BBB+	Baa1	BBB+	13		
	BBB	Baa2	BBB	12		
	BBB-	Baa3	BBB-	11		
Non-investment grade	BB+	Ba1	BB+	10		
	BB	Ba2	BB	9		
	BB-	Ba3	BB-	8		
	B+	B1	B+	7		
	B	B2	B	6		
	B-	B3	B-	5		
	CCC+	Caa1	CCC+	4		
	CCC	Caa2	CCC	3		
	CCC-	Caa3	CCC-	2		
	CC/C	Ca/C	CC/C	1		
	SD/D		RD/D	0		

This table assign numerical values to letter credit ratings and outlooks from S&P, Moody’s and Fitch.

Appendix 2

Table 36 Cointegration test results for CDS & ratings

	CDS & Rating						
	ADF		Johansen Trace		Johansen eigenvalue		
Country	t stat	lags	r=0	r=1	r=0	r=1	lags
Asia							
China	-2.147	1	17.325	5.3215	12.004	5.321	4
Indonesia	-2.221	1	**17.914**	5.077	12.837	5.077	2
Japan	**-2.781**	1	9.949	2.513	7.436	2.513	5
Kazakhstan	-1.262	1	9.72	3.684	6.036	3.684	2
Korea	-1.670	1	8.736	2.758	5.979	2.758	4
Malaysia							
Philippines	**-2.746**	1	15.783	1.14	**14.643**	1.14	8
Thailand	-2.334	1	-	-	-	-	
Latin America							
Argentina	**-4.288**	1	**24.235**	3.289	**20.946**	3.289	12
Brazil	**-2.589**	1	**25.65**	6.12	**19.53**	6.12	2
Chile	-2.067	1	12.362	3.629	8.733	3.629	1
Colombia	**-2.811**	1	**21.026**	4.005	**17.021**	4.005	2
Mexico	-2.274	1	**18.527**	7.382	11.145	7.382	2
Panama	**-2.583**	1	11.937	5.238	6.7	5.238	12
Peru	**-2.998**	1	**20.842**	8.643	12.199	8.643	2
Venezuela	-1.106	1	16.6	1.918	**14.702**	1.918	2
Europe							
Austria	-1.805	1	6.357	2.595	3.763	2.595	5
Belgium	-1.242	1	12.276	3.138	9.138	3.137	4
Bulgaria	-0.846	1	**23.589**	5.357	**18.232**	5.357	2
Croatia	-2.100	1	-	-	-	-	
France	-1.791	1	6.006	1.7	4.31	1.696	8
Greece	-1.247	1	**28.992**	2.356	**26.636**	2.356	12
Hungary	-1.870	1	**26.603**	2.879	**23.7**	2.879	2
Ireland	**-3.427**	1	16.932	2.104	**14.828**	2.104	7
Italy	-1.293	1	16.089	2.519	13.57	2.519	12
Poland	-1.405	1	12.265	3.346	8.919	3.346	6
Portugal	-1.656	1	16.629	4.975	11.954	4.675	7
Romania	-1.047	1	**32.367**	3.626	**28.741**	3.626	1
Russia	-1.515	1	**36.788**	7.123	**29.666**	7.123	2
Slovak							
Spain	-1.505	1	**41.501**	2.258	**39.243**	2.258	12
Ukraine	**-5.540**	1	**31.582**	2.603	**28.98**	2.603	12
MidEast & Latin							
Israel	**-4.038**	1	**21.528**	4.72	**16.808**	4.72	3
Lebanon	**-3.221**	1	9.929	1.039	8.89	1.039	10
Qatar	-1.860	1	16.89	7.329	9.56	7.329	7
South Africa							
Turkey	**-2.840**	1	13.097	4.652	8.445	4.652	2

The cointegration results of sovereign CDS spreads and ratings for the Augmented Dickey Fuller (ADF), Johansen Trace, and Max eigenvalue test statistics (with restricted constant) are reported, while the lags are selected by AIC. For the ADF test, critical values are taken from the Mackinnon Critical value. Where the null hypothesis of a unit root is rejected at the 10% level of probability, figures are emphasized in bold. For the Johansen trace and max eigenvalue tests, the null hypothesis r=0 and r=1 denotes there is no cointegration relation and one cointegration relation respectively; again, where the null hypothesis is rejected at the 10% level, figures are emphasized in bold.

Table 37 Cointegration test results for CDS & outlooks

	CDS & Outlook						
	ADF		Johansen Trace		Johansen eigenvalue		
Country	t stat	lags	r=0	r=1	r=0	r=1	lags
Asia							
China	**-2.726**	1	15.131	2.44	12.69	2.44	4
Indonesia	-2.446	1	9.891	3.193	6.698	3.193	3
Japan	**-3.359**	1	13.678	1.292	12.386	1.292	8
Kazakhstan	-1.927	1	-	-	-	-	
Korea	-1.729	1	6.934	1.438	5.496	1.438	5
Malaysia	-1.753	1	7.537	2.13	5.408	2.13	10
Philippines	**-2.787**	1	14.353	5.022	9.331	5.022	3
Thailand	-1.708	1	10.425	3.637	6.788	3.637	4
Latin America							
Argentina	**-4.563**	1	**23.201**	3.682	**19.519**	3.682	12
Brazil	**-2.751**	1	15.206	6.776	8.43	6.776	2
Chile	-1.378	1	-	-	-	-	
Colombia	**-3.449**	1	15.95	3.837	12.113	3.836	3
Mexico	**-2.829**	1	-	-	-	-	
Panama	**-2.611**	1	13.912	4.592	9.32	4.592	1
Peru	**-3.439**	1	-	-	-	-	
Venezuela	-1.835	1	10.589	1.38	9.209	1.38	5
Europe							
Austria	-1.770	1	9.245	2.685	6.561	2.685	5
Belgium	-1.964	1	12.705	2.677	10.028	2.677	4
Bulgaria	-1.927	1	8.283	1.68	6.603	1.68	2
Croatia	-1.419	1	**21.577**	1.676	**19.9**	1.676	1
France	-1.710	1	7.901	1.727	6.174	1.727	10
Greece	-1.683	1	15.608	6.3	9.309	6.3	1
Hungary	-2.362	1	**35.116**	3.544	**31.572**	3.544	2
Ireland	**-4.708**	1	**22.566**	2.111	**20.455**	2.111	5
Italy	-0.947	1	8.809	2.04	6.77	2.04	4
Poland	-1.971	1	-	-	-	-	
Portugal	-1.977	1	10.674	3.7	6.976	3.7	8
Romania	-1.033	1	8.175	2.056	6.119	2.056	2
Russia	-1.615	1	**18.887**	5.5	13.39	5.5	2
Slovak	-1.336	1	10.533	1.62	8.913	1.62	1
Spain	-2.219	1	8.715	2.856	5.859	2.856	7
Ukraine	**-6.406**	1	**18.866**	1.7	**17.171**	1.7	12
MidEast & Africa							
Israel	-	-	-	-	-	-	
Lebanon	**-3.243**	1	15.605	5.634	9.97	5.634	3
Qatar	-	-	-	-	-	-	
South Africa	-1.356	1	13.824	3.914	9.91	3.914	2
Turkey	**-2.934**	1	**24.523**	6.884	**17.638**	6.884	2

The cointegration results of sovereign CDS spreads and outlooks for the Augmented Dickey Fuller (ADF), Johansen Trace, and Max eigenvalue test statistics (with restricted constant) are reported, while the lags are selected by AIC. For the ADF test, critical values are taken from the Mackinnon Critical value. Where the null hypothesis of a unit root is rejected at the 10% level of probability, figures are emphasized in bold. For the Johansen trace and max eigenvalue tests, the null hypothesis r=0 and r=1 denotes there is no cointegration relation and one cointegration relation respectively; again, where the null hypothesis is rejected at the 10% level, figures are emphasized in bold.

Appendix 3

Table 38 Information criterion for VECM lag selection, CDS & Rating

lag	1	2	3	4	5	6	7	8	9	10	11	12
Asia												
China	-13.8179	-13.8165	-13.8251	**-13.8303**	-13.8266	-13.8233	-13.8284	-13.8251	-13.8228	-13.8194	-13.8179	-13.8154
Indonesia	-13.8173	**-13.822**	-13.8181	-13.8161	-13.8146	-13.8115	-13.8103	-13.8091	-13.8068	-13.8055	-13.8037	-13.8003
Japan	-11.221	-11.2476	-11.2833	-11.2943	**-11.2992**	-11.298	-11.2968	-11.2934	-11.2906	-11.2868	-11.2851	-11.2821
Kazakhstan	-14.1737	**-14.1948**	-14.1912	-14.1891	-14.1886	-14.1871	-14.1857	-14.1843	-14.1822	-14.1819	-14.1944	-14.1927
Korea	-14.5219	-14.5235	-14.527	**-14.5274**	-14.5269	-14.5242	-14.5221	-14.5209	-14.5208	-14.5188	-14.519	-14.5182
Malaysia	-15.983	-15.9826	-15.9791	-15.9811	-15.98	-15.9763	-15.9926	-15.9937	-16.0011	-16.0033	-16.0097	**-16.0225**
Philippines	-14.1811	-14.1846	-14.1812	-14.178	-14.1741	-14.1706	-14.1822	**-14.1865**	-14.1844	-14.1804	-14.1801	-14.1783
Thailand	**-15.1805**	-15.1773	-15.1754	-15.1739	-15.1701	-15.1672	-15.1651	-15.1647	-15.1668	-15.1664	-15.164	-15.1617
Latin America												
Argentina	-9.28925	-9.35518	-9.35208	-9.40459	-9.40792	-9.40399	-9.40103	-9.41776	-9.46312	-9.46341	-9.46116	**-9.48456**
Brazil	-13.4765	**-13.4811**	-13.478	-13.4745	-13.4712	-13.475	-13.4771	-13.4748	-13.4758	-13.475	-13.476	-13.4774
Chile	**-13.6203**	-13.6168	-13.6129	-13.6122	-13.6096	-13.6063	-13.6037	-13.6002	-13.6021	-13.5995	-13.5973	-13.5941
Colombia	-14.3306	**-14.3428**	-14.3393	-14.3354	-14.334	-14.3344	-14.3336	-14.3311	-14.3326	-14.3318	-14.3324	-14.3295
Mexico	-14.1534	**-14.1779**	-14.1747	-14.1714	-14.1683	-14.1652	-14.169	-14.1652	-14.1622	-14.1589	-14.1615	-14.1615
Panama	-14.5307	-14.5286	-14.527	-14.5265	-14.523	-14.5231	-14.5209	-14.5192	-14.516	-14.5181	-14.5154	**-14.5534**
Peru	-13.8455	**-13.8569**	-13.8531	-13.8498	-13.8467	-13.847	-13.8436	-13.8403	-13.8469	-13.8466	-13.8469	-13.8446
Venezuela	-12.2811	**-12.3168**	-12.3139	-12.3109	-12.3072	-12.3038	-12.3003	-12.2989	-12.2977	-12.299	-12.2969	-12.2941
Europe												
Austria	-11.5036	-11.5368	-11.5595	-11.5715	**-11.584**	-11.5803	-11.579	-11.5756	-11.575	-11.5723	-11.5692	-11.5671
Belgium	-11.8694	-11.9843	-11.9885	**-12.0096**	-12.0083	-12.0065	-12.0069	-12.0035	-12.0002	-11.9963	-11.9927	-11.9893
Bulgaria	-13.5577	**-13.5836**	-13.5805	-13.583	-13.5816	-13.5819	-13.5791	-13.5759	-13.5725	-13.5693	-13.5665	-13.5634
Croatia	-15.3738	-15.3776	-15.3745	**-15.3872**	-15.3835	-15.3817	-15.3778	-15.3741	-15.372	-15.3719	-15.3681	-15.3684
France	-11.5912	-11.6391	-11.6536	-11.6644	-11.676	-11.6726	-11.6749	**-11.6774**	-11.6743	-11.6735	-11.6697	-11.6657
Greece	-10.8468	-10.8434	-10.8396	-10.8381	-10.836	-10.8328	-10.8324	-10.829	-10.8622	-10.8636	-10.863	**-10.8699**

Hungary	-13.2273	**-13.2294**	-13.2263	-13.2228	-13.2235	-13.2202	-13.2201	-13.2174	-13.2141	-13.2102	-13.2073	-13.2051
Ireland	-8.42227	-8.45687	-8.48275	-8.48966	-8.49043	-8.48647	**-8.54026**	-8.53771	-8.53434	-8.53095	-8.52781	-8.52565
Italy	-12.7742	-12.7813	-12.7804	-12.7955	-12.7926	-12.7908	-12.7889	-12.7862	-12.7834	-12.7796	-12.8059	**-12.821**
Poland	-14.8962	-14.8922	-14.8895	-14.8859	-14.8948	**-14.9125**	-14.9102	-14.9065	-14.9051	-14.9014	-14.8998	-14.8996
Portugal	-11.2067	-11.206	-11.2032	-11.2133	-11.2137	-11.2118	**-11.3013**	-11.2996	-11.2966	-11.2975	-11.2963	-11.2935
Romania	**-13.6047**	-13.604	-13.6002	-13.6005	-13.6002	-13.5964	-13.5934	-13.5896	-13.5903	-13.5909	-13.5898	-13.5913
Russia	-13.7803	**-13.7887**	-13.7849	-13.7812	-13.7801	-13.7802	-13.7785	-13.7752	-13.7761	-13.7745	-13.771	-13.7682
Slovak	**-13.1823**	-13.1807	-13.1773	-13.1744	-13.1734	-13.175	-13.1721	-13.1759	-13.1729	-13.1697	-13.1721	-13.1682
Spain	-10.2418	**-10.2677**	-10.2714	-10.3017	-10.3031	-10.3011	-10.3043	-10.3138	-10.312	-10.3086	-10.32	-10.3231
Ukraine	-10.0892	**-10.3018**	-10.3803	-10.4146	-10.4276	-10.4325	-10.4881	-10.4879	-10.5014	-10.498	-10.4943	-10.5408
Middle Ease & Africa												
Israel	-14.6704	-14.6666	**-14.6731**	-14.6717	-14.6688	-14.6653	-14.6614	-14.6615	-14.6581	-14.656	-14.6523	-14.6525
Lebanon	-13.8754	-13.9123	-13.9305	-13.927	-13.9233	-13.9233	-13.9203	-13.9172	-13.914	**-13.9351**	-13.9321	-13.9301
Qatar	-13.0212	-13.0416	-13.0383	-13.0407	-13.0495	-13.0516	**-13.0535**	-13.0521	-13.0491	-13.0459	-13.0453	-13.0427
South Africa	-14.2564	-14.2811	-14.2784	-14.2744	-14.2763	-14.3442	**-14.3835**	-14.38	-14.3773	-14.3735	-14.3716	-14.3688
Turkey	-14.3469	**-14.3542**	-14.3512	-14.3474	-14.3446	-14.345	-14.3429	-14.3393	-14.3382	-14.3358	-14.3332	-14.3315

This table presents the Akaike's Information Criterion (AIC) in the VECM/cointegration/Granger causality lag selection of CDS & Rating, from lag 1 to lag 12. The minimized AIC are highlighted in bold, which corresponds to the lag selection in the Johansen test in Table 36.

Table 39 Information criterion for VECM lag selection, CDS & Outlook

lag	1	2	3	4	5	6	7	8	9	10	11	12
Asia												
China	-13.7575	-13.7594	-13.7599	**-13.7649**	-13.7609	-13.7583	-13.7636	-13.7607	-13.7588	-13.7552	-13.753	-13.7505
Indonesia	-13.6929	-13.6984	**-13.6996**	-13.6969	-13.6963	-13.6929	-13.6915	-13.6897	-13.6867	-13.6852	-13.6842	-13.6817
Japan	-11.3183	-11.3452	-11.3845	-11.3953	-11.4002	-11.3984	-11.3971	**-11.404**	-11.4016	-11.398	-11.3969	-11.3941
Kazakhstan	-13.8081	-13.8297	**-13.8335**	-13.8335	-13.8308	-13.8275	-13.8236	-13.8209	-13.8179	-13.8174	-13.8145	-13.8108
Korea	-14.8089	-14.8093	-14.8085	-14.809	**-14.8106**	-14.8075	-14.8052	-14.8085	-14.8094	-14.8063	-14.8038	-14.802
Malaysia	-14.4445	-14.4434	-14.4543	-14.4563	-14.4531	-14.4538	-14.4614	-14.4629	-14.462	**-14.4744**	-14.4725	-14.4704
Philippines	-13.7206	-13.7247	**-13.7419**	-13.7386	-13.7354	-13.7325	-13.7323	-13.7353	-13.7328	-13.7288	-13.7286	-13.7269
Thailand	-13.7433	-13.7399	-13.738	**-13.7676**	-13.7639	-13.7604	-13.7594	-13.7585	-13.761	-13.759	-13.758	-13.7554
Latin America												
Argentina	-11.8357	-11.9019	-11.8988	-11.9872	-11.9906	-11.9866	-11.9848	-12.0009	-12.0466	-12.047	-12.0446	**-12.068**
Brazil	-13.3601	**-13.3656**	-13.3639	-13.3607	-13.3582	-13.3563	-13.3586	-13.3554	-13.3541	-13.3528	-13.3535	-13.3549
Chile	**-13.6207**	-13.6173	-13.6143	-13.6118	-13.6091	-13.606	-13.6041	-13.6019	-13.6072	-13.6046	-13.6021	-13.6021
Colombia	-13.5542	-13.567	**-13.5692**	-13.5665	-13.564	-13.5644	-13.5623	-13.5591	-13.5625	-13.5617	-13.5625	-13.5657
Mexico	-14.018	**-14.0443**	-14.0413	-14.0394	-14.0385	-14.0345	-14.039	-14.0363	-14.0357	-14.0323	-14.0345	-14.0346
Panama	**-13.8899**	-13.8878	-13.8885	-13.8885	-13.885	-13.8849	-13.882	-13.8797	-13.8771	-13.8782	-13.8857	-13.8866
Peru	-13.3328	**-13.3445**	-13.3416	-13.3428	-13.3421	-13.3436	-13.3404	-13.3368	-13.3367	-13.3403	-13.34	-13.3374
Venezuela	-14.6084	-14.6413	-14.6389	-14.6371	**-14.6543**	-14.6514	-14.6476	-14.6461	-14.6448	-14.6474	-14.6477	-14.644
Europe												
Austria	-12.198	-12.2313	-12.2541	-12.2665	**-12.2791**	-12.2757	-12.2742	-12.2705	-12.2699	-12.2672	-12.2641	-12.262
Belgium	-12.3697	-12.4838	-12.488	**-12.5086**	-12.5073	-12.5055	-12.5057	-12.5021	-12.4992	-12.4956	-12.4949	-12.4915
Bulgaria	-12.974	**-12.998**	-12.9959	-12.9929	-12.9923	-12.9922	-12.9887	-12.9862	-12.9823	-12.9798	-12.9772	-12.9738
Croatia	**-14.1266**	-14.1245	-14.1222	-14.1223	-14.1191	-14.1156	-14.1129	-14.1166	-14.1134	-14.1142	-14.1112	-14.1121
France	-12.5749	-12.6229	-12.6374	-12.6483	-12.6594	-12.6561	-12.6584	-12.6608	-12.6578	**-12.7719**	-12.768	-12.764
Greece	**-13.4526**	-13.4493	-13.4465	-13.4453	-13.445	-13.4418	-13.4425	-13.44	-13.4366	-13.4376	-13.434	-13.4328
Hungary	-13.4542	**-13.4555**	-13.4532	-13.4495	-13.4502	-13.4463	-13.4455	-13.4415	-13.4376	-13.4336	-13.4351	-13.4344
Ireland	-10.3243	-10.3604	-10.3853	-10.392	**-10.3926**	-10.3886	-10.3887	-10.3863	-10.3828	-10.3803	-10.3782	-10.3758

Italy	-13.4627	-13.4686	**-13.4685**	-13.4976	-13.4942	-13.4919	-13.4904	-13.4877	-13.484	-13.4808	-13.478	-13.4753
Poland	-13.7953	-13.8206	-13.8185	-13.8153	-13.8257	-13.8446	-13.8522	-13.8501	-13.8524	-13.8588	**-13.864**	-13.8634
Portugal	-12.98	-12.9784	-12.9831	-12.9858	-12.9862	-12.9848	-12.9848	**-12.988**	-12.9842	-12.9822	-12.981	-12.9773
Romania	-13.9128	**-13.9129**	-13.9095	-13.9093	-13.906	-13.9023	-13.9003	-13.8964	-13.894	-13.8912	-13.89	-13.8892
Russia	-13.6676	**-13.6764**	-13.673	-13.6716	-13.6758	-13.6731	-13.6698	-13.6678	-13.6719	-13.6719	-13.6687	-13.6666
Slovak	**-12.8798**	-12.8762	-12.8724	-12.8701	-12.8694	-12.8703	-12.8667	-12.8725	-12.8692	-12.867	-12.8667	-12.8634
Spain	-12.0159	-12.0412	-12.0444	-12.0725	-12.079	-12.0784	**-12.0812**	-12.0797	-12.0771	-12.0758	-12.0786	-12.0808
Ukraine	-9.65105	-9.85992	-9.93751	-9.97179	-10.001	-10.0047	-10.0047	-10.0391	-10.0398	-10.0644	-10.0654	**-10.0687**
Middle Ease & Africa												
Israel	-10.7572	-10.7533	-10.7579	**-10.7589**	-10.7566	-10.7557	-10.752	-10.7549	-10.7517	-10.7536	-10.7503	-10.7503
Lebanon	-12.1914	-12.2279	**-12.2462**	-12.2423	-12.2385	-12.2383	-12.2354	-12.2324	-12.2294	-12.2307	-12.2276	-12.2333
Qatar	-14.7007	**-14.7017**	-14.7002	-14.701	-14.6981	-14.697	-14.6965	-14.6953	-14.6918	-14.6885	-14.685	-14.6817
South Africa	-10.6165	**-10.6407**	-10.6377	-10.6337	-10.6354	-10.6391	-10.6357	-10.6317	-10.6289	-10.6249	-10.6233	-10.6195
Turkey	-12.2422	**-12.2505**	-12.2471	-12.2434	-12.2401	-12.2388	-12.2368	-12.2336	-12.231	-12.229	-12.2254	-12.2237

This table presents the Akaike's Information Criterion (AIC) in the VECM/cointegration/Granger causality lag selection of CDS & Outlook, from lag 1 to lag 12. The minimized AIC are highlighted in bold, which corresponds to the lag selection in the Johansen test in Table 37.

Appendix 4

Table 40 Ljung-Box test for error in VECM for Rating & CDS

Lag	1	2	3	4
Asia				
China				
Indonesia	**0.991**	**0.993**	**0.853**	**0.352**
Japan	**0.128**	0	0	0
Kazakhstan				
Korea				
Malaysia				
Philippines	**0.927**	**0.501**	**0.537**	**0.704**
Thailand	**0.969**	**0.366**	**0.167**	**0.268**
Latin America				
Argentina	**0.341**	0.047	0	0
Brazil	**0.971**	**0.907**	**0.89**	**0.921**
Chile				
Colombia	**0.954**	**0.867**	**0.962**	**0.781**
Mexico	**0.927**	**0.904**	**0.58**	**0.688**
Panama	**0.942**	**0.158**	0.048	**0.084**
Peru	**0.976**	**0.957**	**0.81**	**0.913**
Venezuela	**0.908**	**0.972**	**0.582**	**0.7**
Europe				
Austria				
Belgium				
Bulgaria	**0.803**	**0.605**	**0.507**	**0.423**
Croatia				
France				
Greece	**0.87**	**0.921**	**0.731**	**0.456**
Hungary	**0.933**	**0.975**	**0.978**	**0.208**
Ireland	**0.189**	0	0	0
Italy				
Poland				
Portugal				
Romania	**0.983**	**0.897**	**0.097**	**0.114**
Russia	**0.971**	**0.887**	**0.913**	**0.164**
Slovak				
Spain	**0.507**	0	0	0
Ukraine	**0305**	0	0	0
MidEast & Latin				
Israel	**0.999**	0.001	0.001	0.001
Lebanon	**0.189**	0	0	0
Qatar				
South Africa				
Turkey	**0.922**	**0.66**	**0.784**	**0.548**

The Ljung–Box test statistic (p-value) for examining the null hypothesis of independence in the error term is computed. We try several lag values (1, 2, 3, 4) and see if the conclusion reached changes for different values. If not, then the conclusion to reach is clear, whereas if rejecting white noise or no changes for different values of m, then the conclusion is that the data are close to white noise but perhaps not actually white noise. The results show that all countries have white noise at lag 1, and most of them retain white noise with more lags, which proves that our assumption of error is adequate.

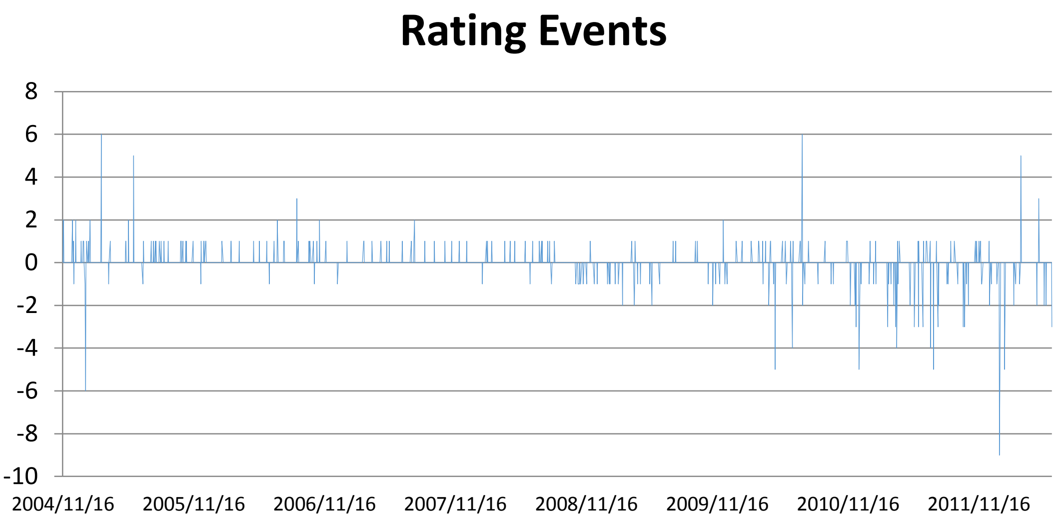
Table 41 Ljung-Box test for error in VECM for Outlook & CDS

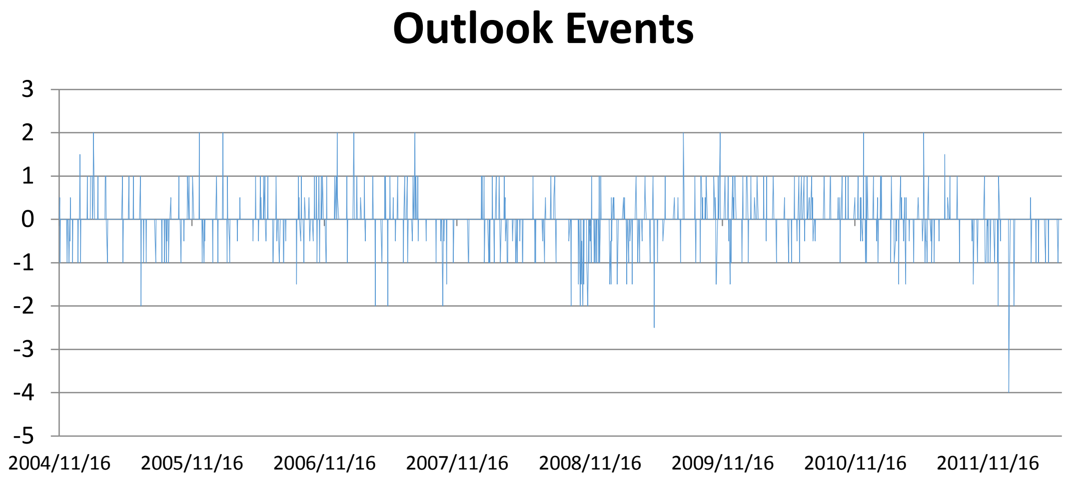
Lag	1	2	3	4
Asia				
China	**0.893**	**0.962**	0.001	0.002
Indonesia				
Japan	**0.132**	0	0	0
Kazakhstan				
Korea				
Malaysia				
Philippines	**0.906**	**0.509**	**0.549**	**0.714**
Thailand				
Latin America				
Argentina	**0.3**	0.038	0	0
Brazil	**0.988**	**0.887**	**0.883**	**0.915**
Chile				
Colombia	**0.937**	**0.843**	**0.948**	**0.804**
Mexico	**0.91**	**0.904**	0.6	**0.701**
Panama	**0.956**	**0.158**	0.049	0.084
Peru	**0.968**	**0.966**	**0.832**	**0.926**
Venezuela				
Europe				
Austria				
Belgium				
Bulgaria				
Croatia	**0.868**	**0.472**	0.023	0.044
France				
Greece				
Hungary	**0.962**	**0.998**	**0.953**	**0.276**
Ireland	**0.207**	0	0	0
Italy				
Poland				
Portugal				
Romania				
Russia	**0.958**	**0.882**	**0.87**	**0.16**
Slovak				
Spain				
Ukraine	**0.845**	0	0	0
MidEast & Latin				
Israel				
Lebanon	**0.195**	0	0	0
Qatar				
South Africa	**0.875**	**0.701**	**0.727**	0.09
Turkey	**0.911**	**0.633**	**0.767**	**0.537**

The Ljung–Box test statistic (p-value) for examining the null hypothesis of independence in the error term is computed. We try several lag values (1, 2, 3, 4) and see if the conclusion reached changes for different values. If not, then the conclusion to reach is clear, whereas if rejecting white noise or no changes for different values of m, then the conclusion is that the data are close to white noise but perhaps not actually white noise. The results show that all countries have white noise at lag 1, and most of them retain white noise with more lags, which proves that our assumption of error is adequate.

Appendix 5

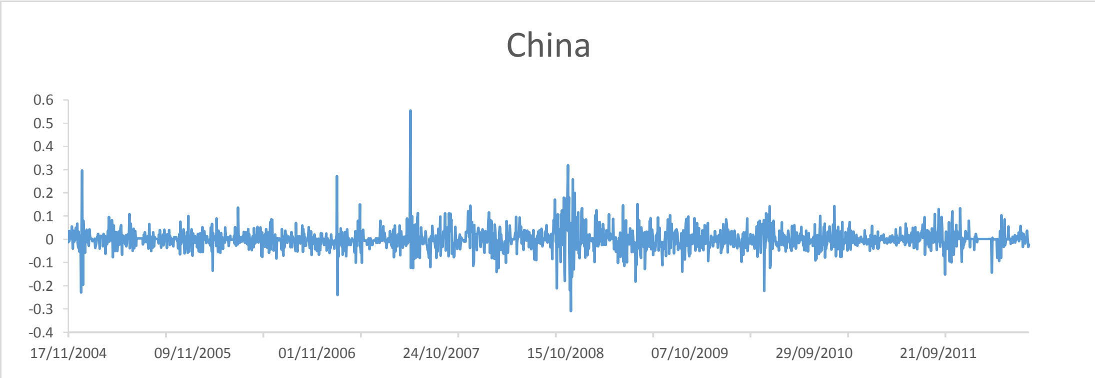
Figure 22 Rating and Outlook events distribution from 2004 to 2012

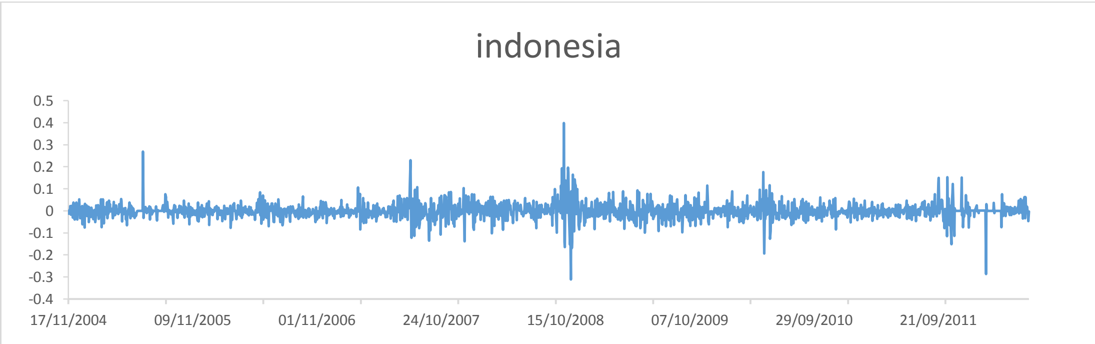


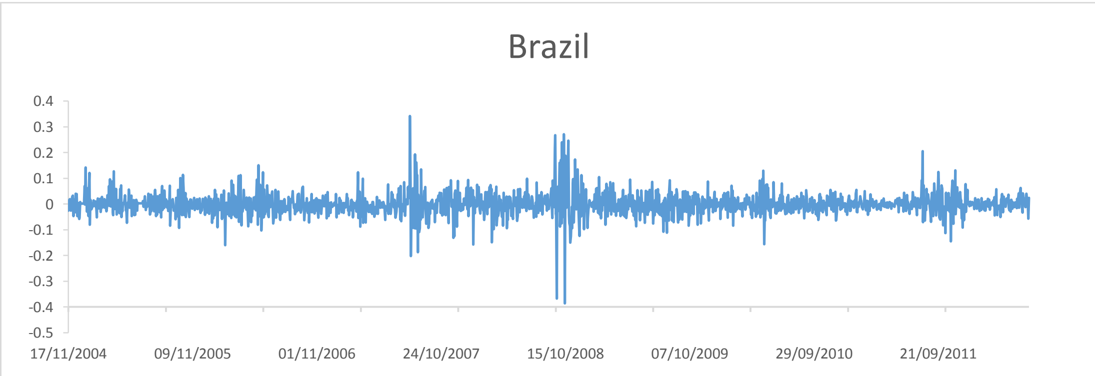


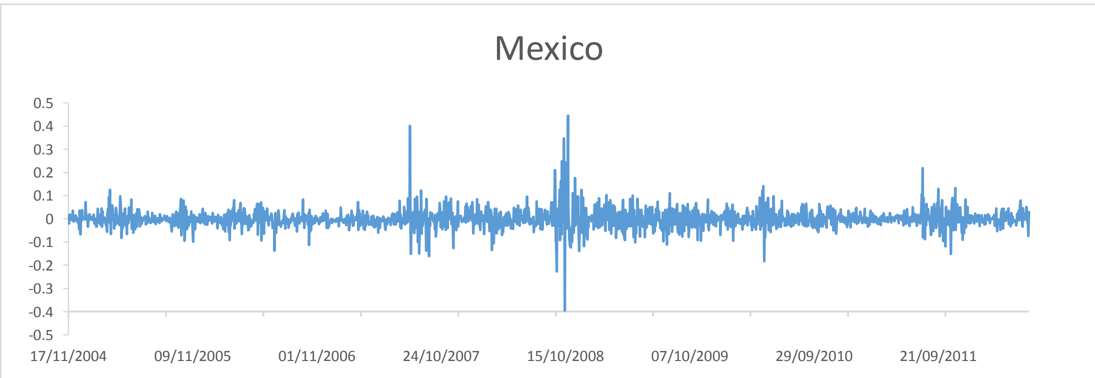
Appendix 6

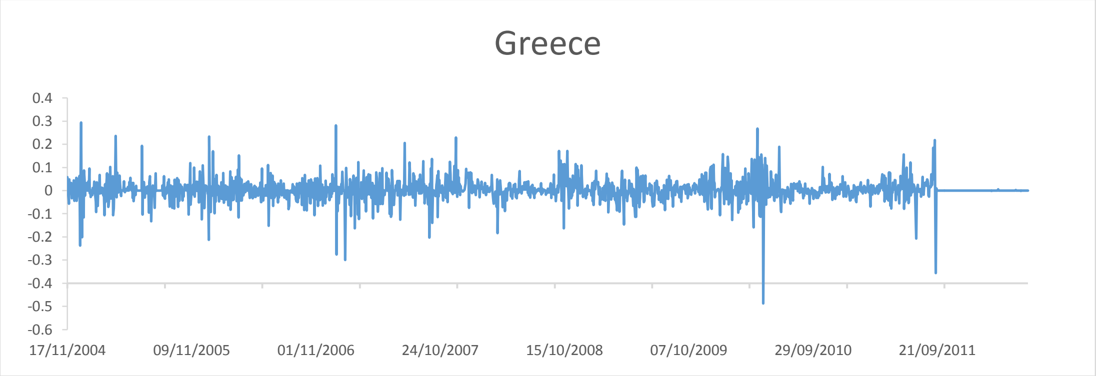
Figure 23 Error plot for VECM analysis of CDS and Rating

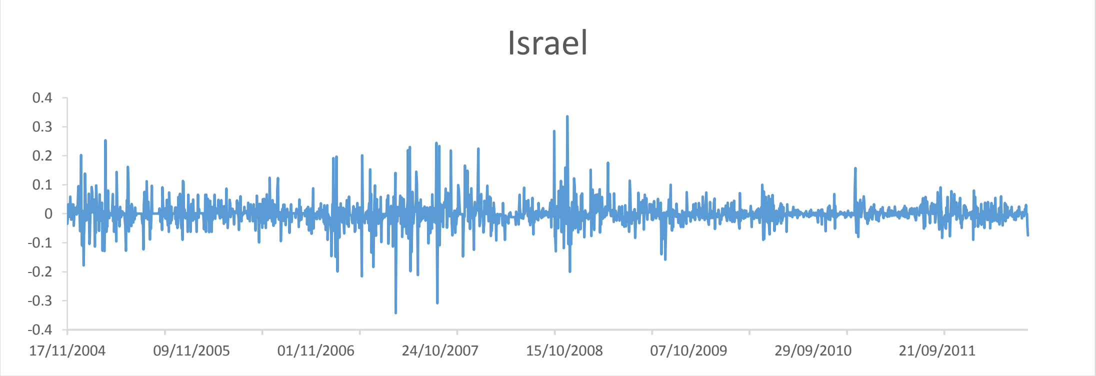






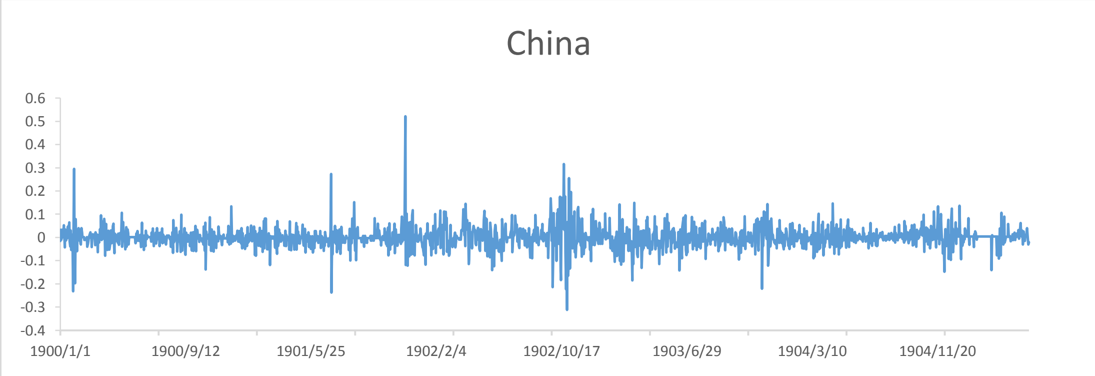


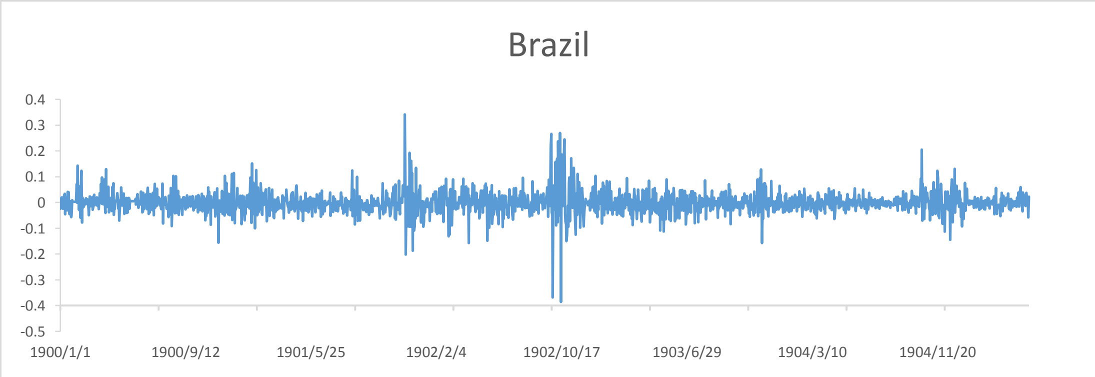


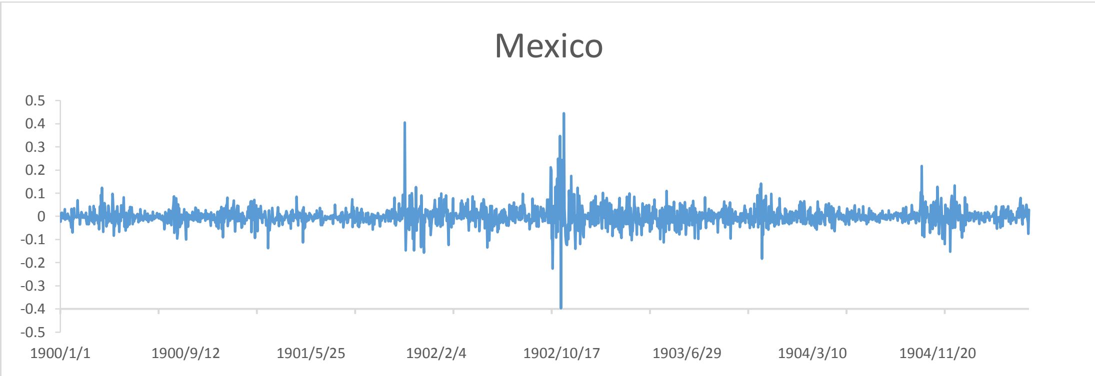


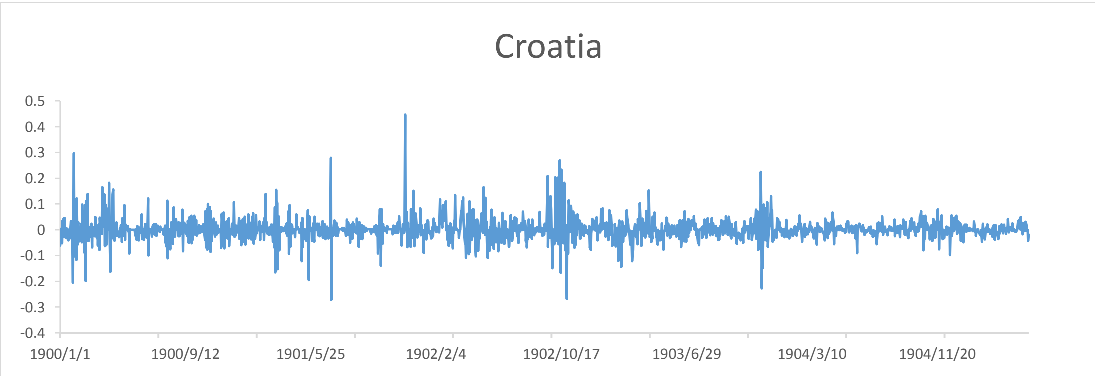
The figures plot the error term from the VECM analysis for sovereign CDS spreads and credit ratings. These sample countries are selected to represent their regions. Corresponding to the Ljung-Box test for error, the results show that all countries appear to have white noise, which proves that our assumption of error is adequate.

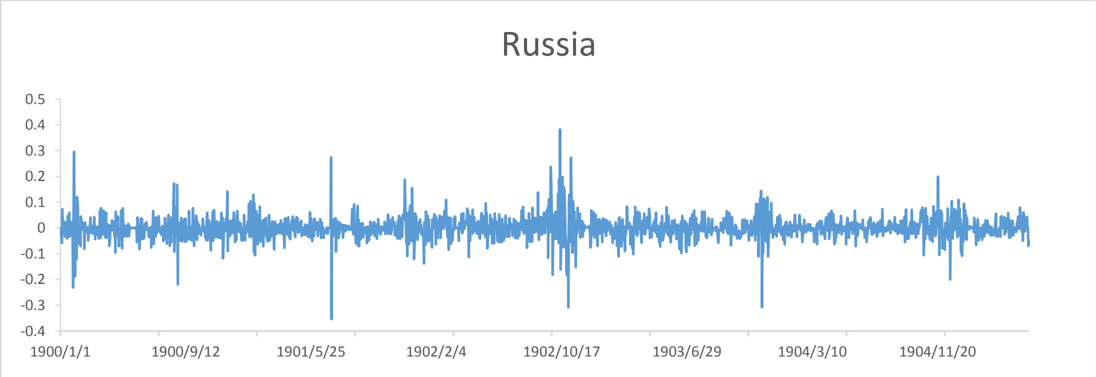
Figure 24 Error plot for VECM analysis of CDS and Outlook

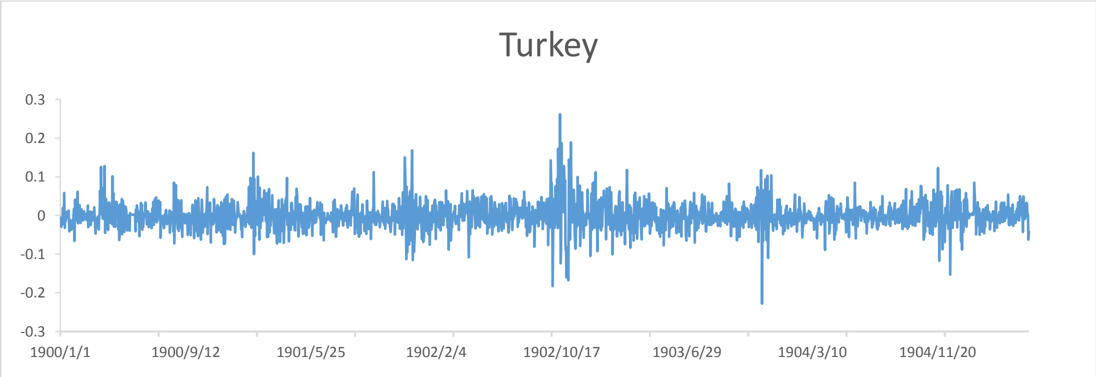










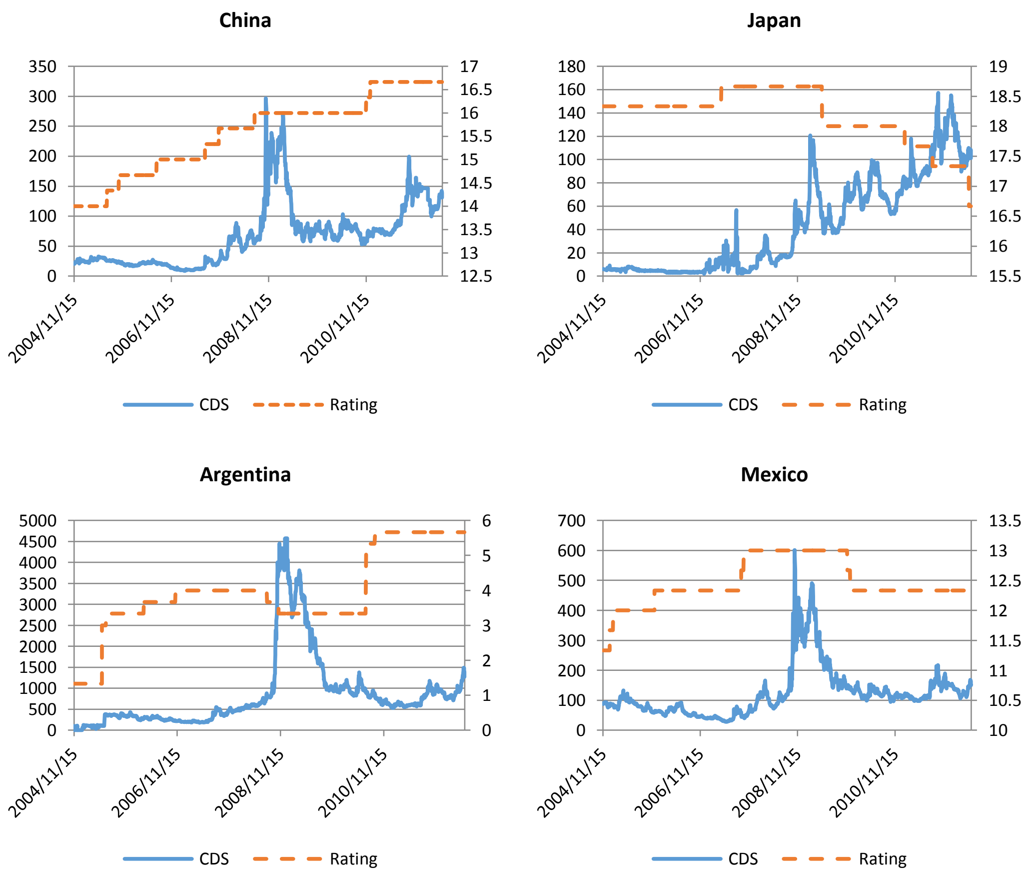


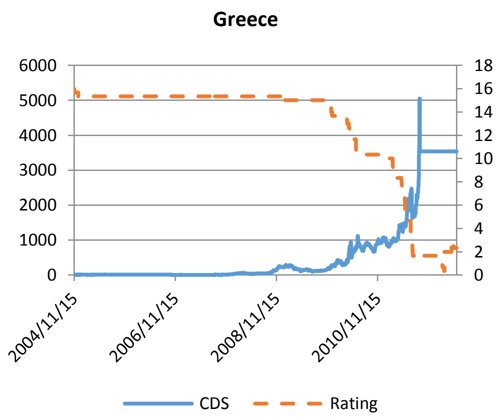
The figures plot the error term from the VECM analysis for sovereign CDS spreads and credit outlook. These sample countries are selected to represent their regions. Corresponding to the Ljung-Box test for error, the results show that all countries appear have white noise, which proves that our assumption of error is adequate.

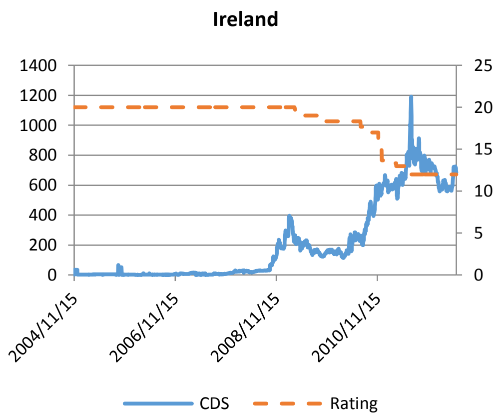
Appendix 7

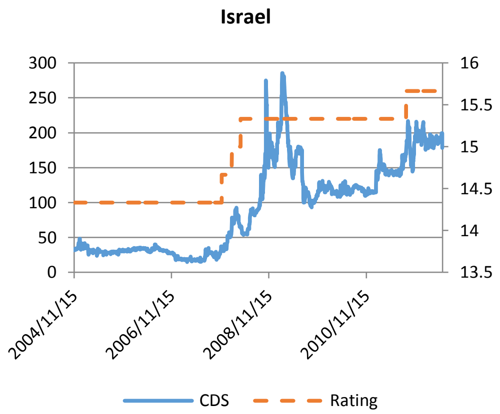
Figure 25 Sovereign CDS spreads and Rating co-movement

Plots of the sovereign CDS spread (solid lines) and the numerical transfer of rating (dashed lines) for all 8 countries. The primary axis (left) show the CDS spread, in bp, while the secondary axis (right) represents the numerical transfer of ratings.




Greece
6000
5000
4000
3000
2000
1000
0
18
16
14
12
10
8
6
4
2
0
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Rating


Ireland
1400
1200
1000
800
600
400
200
0
25
20
15
10
5
0
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Rating


Israel
300
250
200
150
100
50
0
16
15.5
15
14.5
14
13.5
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Rating

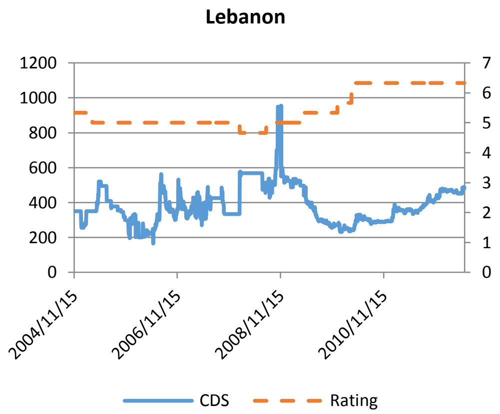
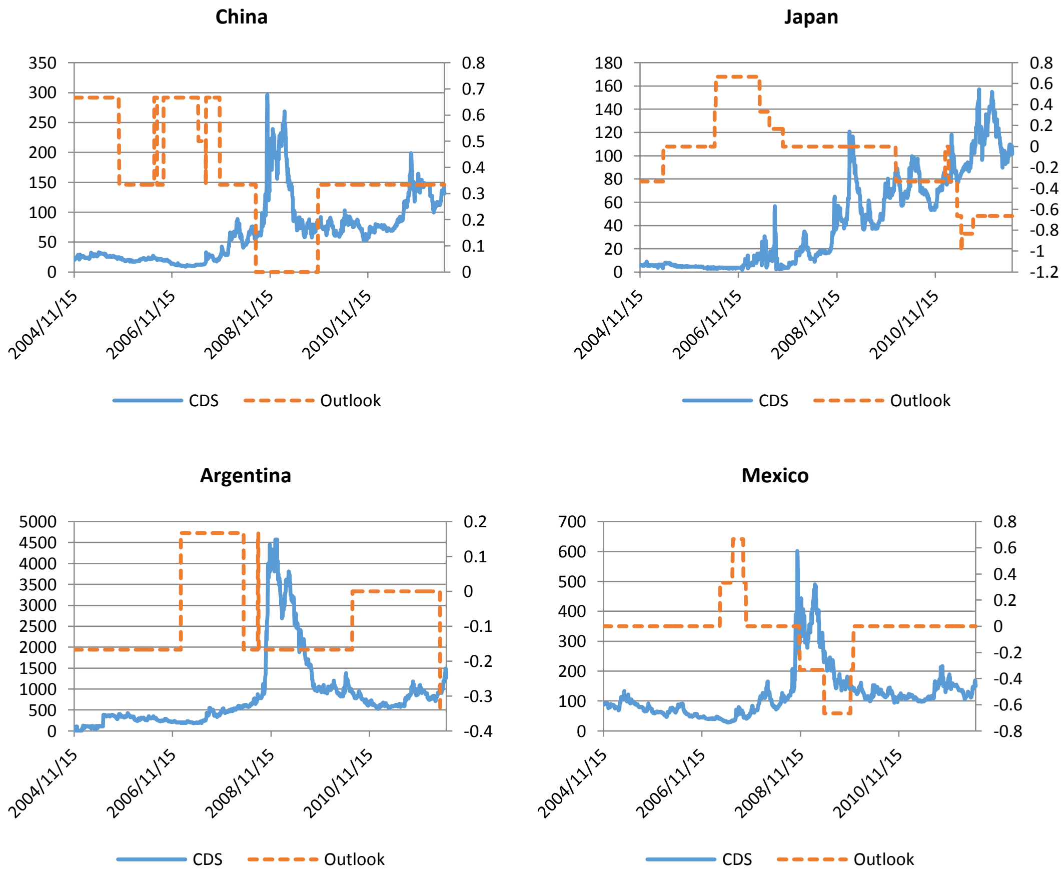
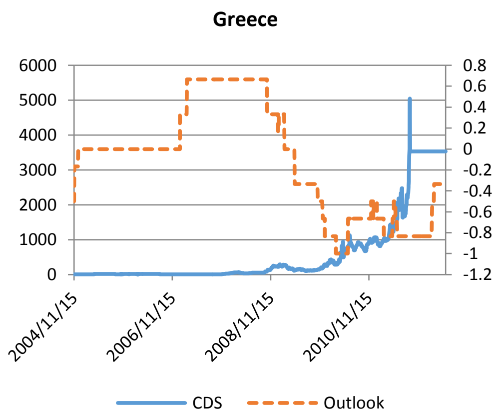
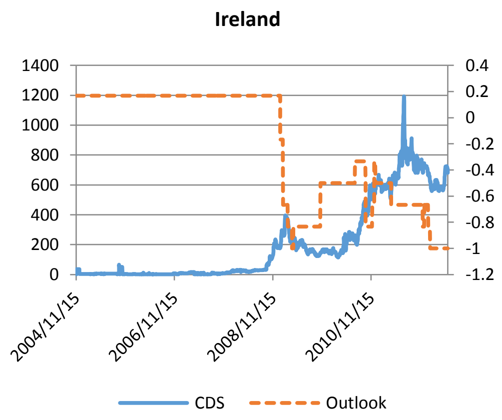

Lebanon
1200
1000
800
600
400
200
0
7
6
5
4
3
2
1
0
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Rating

Figure 26 Sovereign CDS spreads and outlook co-movement

Plots of the sovereign CDS spread (solid lines) and the numerical transfer of outlook (dashed lines) for all 8 countries. The primary axis (left) show the CDS spread, in bp, while the secondary axis (right) represents the numerical transfer of outlook.




Greece
6000
5000
4000
3000
2000
1000
0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Outlook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800
600
400
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0
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-0.4
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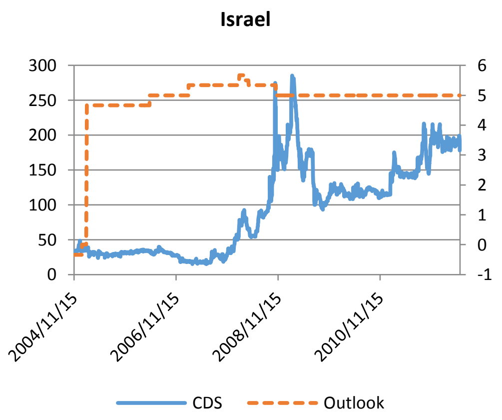
-0.8
-1
-1.2
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Outlook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250
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50
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6
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3
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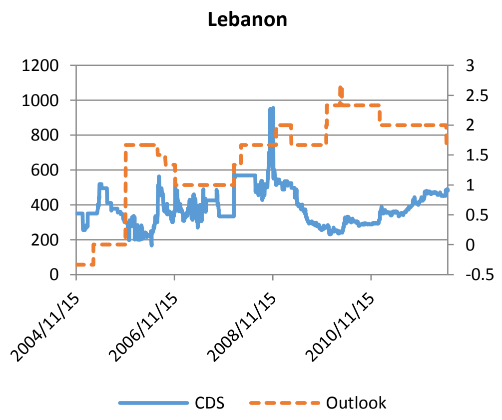
-1
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Outlook


Lebanon
1200
1000
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400
200
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3
2.5
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1.5
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0.5
0
-0.5
2004/11/15
2006/11/15
2008/11/15
2010/11/15
CDS
Outlook

Appendix 8

Table 42 Unit root test for each sub-period

Country	Greece bailout			Ireland bailout		Portugal bailout		Spain bailout	
	before	after 1st	after 2nd	before	after	Before	after	before	after
Austria	-2.59	-1.93	-2.83	-3.29	-0.69	-3.03	-0.69	-2.31	-2.82
Belgium	-2.05	-2.64	-2.8	-1.06	-0.56	-1.44	-0.33	-1.4	-2.2
France	-1.34	-2.77	-2.7	-1.23	-1.54	-1.68	-1.6	-1.51	-1.92
Germany	-2.53	-2.38	-2.96	-3.1	-1.56	-3.06	-1.41	-2.64	-2.56
UK	-2.23	-2.58	-1.47	-2.8	-1.42	-2.89	-1.1	-1.48	-1.61
Greece	0.59	-0.04	-0.84	-0.49	-1.33	-0.55	-2.52	0.16	-
Ireland	-2.77	-0.37	-1.03	-0.21	0.28	-0.48	0.31	-0.92	-1.66
Italy	-1.86	-3.01	-3.29	-2.01	-1.46	-2.49	-2.91	-1.24	-1.77
Portugal	0.15	-0.69	-2.9	-0.58	-0.93	-0.73	-0.59	-0.98	-1.89
Spain	-1.36	-3.15	-3.33	-1.03	-2.28	-1.67	-2.95	-1.36	-1.69

The ADF test indicates the presence of a unit root at the 1% level for all the CDS of 10 countries over each sub-period. The table repots the t-statistics for the null hypothesis of a unit root. For the ADF test, critical values are taken from the Mackinnon Critical value. None of the CDS spreads of 10 countries is stationary at the 1% level of probability.

Appendix 9

Table 43 Cointegration test for Greece's first and second bailout

Event	Variables	Period	ADF	Johansen Trace		Johansen eigenvalue		
			test	r=0	r=1	r=0	r=1	lags
First bailout	GR - AT	before	**-2.697**	16.455	4.245	12.21	4.245	3
		after	**-2.734**	14.196	1.319	12.877	1.319	2
	GR - BG	before	**-2.839**	14.153	4.774	9.379	4.774	2
		after	**-2.585**	9.177	1.079	8.098	1.079	2
	GR - FR	before	-2.135	11.768	3.216	8.551	3.216	2
		after	**-2.795**	13.113	1.174	11.939	1.174	2
	GR - DE	before	**-2.772**	17.764	5.897	11.867	5.897	2
		after	-2.383	0	0	0	0	1
	GR - UK	before	-2.105	14.504	5.733	8.771	5.733	2
		after	**-2.727**	12.388	2.737	9.65	2.737	2
	GR - IR	before	**-2.83**	**18.809**	**7.999**	10.81	**7.999**	2
		after	-1.494	5.215	1.427	3.788	1.427	2
	GR - IT	before	**-3.401**	17.664	5.293	12.371	5.293	2
		after	**-3.008**	15.719	1.825	**13.893**	1.825	2
	GR - PT	before	**-2.716**	10.951	1.87	9.081	1.87	2
		after	-2.523	8.503	1.587	6.916	1.587	2
	GR -SP	before	**-2.921**	14.188	4.563	9.625	4.563	2
		after	**-3.158**	14.087	2.26	11.827	2.26	2
Second bailout	GR - AT	before						
		after	**-3.993**	**26.121**	5.969	**20.152**	5.969	2
	GR - BG	before						
		after	-2.171	13.516	4.625	8.89	4.625	2
	GR - FR	before						
		after	**-3.491**	**19.135**	5.266	**13.869**	5.266	2
	GR - DE	before						
		after	**-2.798**	14.555	4.108	10.448	4.108	3
	GR - UK	before						
		after	**-3.159**	**18.021**	4.812	13.209	4.812	2
	GR - IR	before						
		after	-2.307	15.681	5.749	9.932	5.749	2
	GR - IT	before						
		after	-2.495	15.418	5.151	10.267	5.151	2
	GR - PT	before						
		after	**-3.036**	17.236	5.065	12.171	5.065	4
	GR - SP	before						
		after	**-4.281**	**26.617**	5.572	**21.044**	5.572	2

The cointegration results of sovereign CDS spreads using Augmented Dickey Fuller (ADF), Johansen Trace, and Max eigenvalue test statistics (with restricted constant) are reported, while the lags are selected by AIC. For the ADF test, critical values are taken from the Mackinnon Critical value. Where the null hypothesis of a unit root is rejected at the 10% of probability, figures are printed in bold. For Johansen trace and max eigenvalue test, the null hypothesis r=0 and r=1 denotes there is no cointegration relation and one cointegration relation respectively. Where the null hypothesis rejected at the 10% level, figures are printed in bold.

Table 44 Cointegration for Ireland's bailout

Event	Variables	Period	ADF	Johansen Trace		Johansen eigenvalue		
			test	r=0	r=1	r=0	r=1	lags
Ireland bailout	IR - AT	before	**-3.178**	17.58	2.9	**14.68**	2.9	5
		after	-1.554	5.858	1.017	4.841	1.017	4
	IR - BG	before	-1.758	4.893	1.047	3.846	1.047	7
		after	-1.921	7.206	0.965	6.241	0.965	8
	IR - FR	before	-1.447	3.459	0.708	2.751	0.708	4
		after	-2.019	8.33	0.827	7.503	0.827	12
	IR - DE	before	**-3.096**	7.413	0.728	6.685	0.728	5
		after	-2.355	7.367	0.771	6.597	0.771	4
	IR - UK	before	**-2.832**	0	0	0	0	1
		after	-1.895	6.247	1.256	4.991	1.256	8
	IR - GR	before	-1.384	9.53	3.047	6.483	3.047	7
		after	-1.598	13.84	4.941	8.899	4.941	8
	IR - IT	before	-2.046	**17.982**	1.208	**16.774**	1.208	9
		after	-1.393	10.462	3.273	7.189	3.273	8
	IR - PT	before	-1.406	8.404	2.435	5.969	2.435	5
		after	-1.561	7.013	1.452	5.561	1.452	4
	IR - SP	before	-1.591	4.731	1.185	3.546	1.185	5
		after	-2.204	7.75	0.983	6.767	0.983	8

The cointegration results of sovereign CDS spreads using Augmented Dickey Fuller (ADF), Johansen Trace, and Max eigenvalue test statistics (with restricted constant) are reported, while the lags are selected by AIC. For the ADF test, critical values are taken from the Mackinnon Critical value. Where the null hypothesis of a unit root is rejected at the 10% of probability, figures are printed in bold. For Johansen trace and max eigenvalue test, the null hypothesis r=0 and r=1 denotes there is no cointegration relation and one cointegration relation respectively. Where the null hypothesis rejected at the 10% level, figures are printed in bold.

Table 45 Cointegration test for Portugal's bailout

Event	Variables	Period	ADF	Johansen Trace		Johansen eigenvalue		
			test	r=0	r=1	r=0	r=1	lags
Portugal bailout	PT - AT	before	**-3.197**	**23.794**	6.385	**17.409**	6.385	5
		after	**-2.783**	11.058	0.425	10.633	0.425	2
	PT - BG	before	**-2.808**	9.624	3.12	6.504	3.12	5
		after	**-2.889**	9.301	0.486	8.815	0.486	2
	PT - FR	before	-2.37	9.457	2.918	6.539	2.918	4
		after	**-3.095**	12.885	0.666	12.219	0.666	2
	PT - DE	before	**-3.109**	13.116	4.78	8.335	4.78	8
		after	-2.384	6.423	0.386	6.037	0.386	4
	PT - UK	before	**-2.925**	12.884	3.794	9.09	3.794	4
		after	-1.698	4.405	0.92	3.485	0.92	2
	PT - GR	before	**-3.456**	11.021	3.559	7.461	3.559	7
		after	**-2.947**	17.165	5.657	11.508	5.657	2
	PT - IR	before	-1.33	8.471	3.283	5.188	3.283	5
		after	-2.338	8.697	1.539	7.158	1.539	4
	PT - IT	before	**-3.083**	11.362	3.395	7.968	3.395	4
		after	**-3.006**	14.829	1.736	13.093	1.736	2
	PT - SP	before	-2.419	6.954	3.083	3.871	3.083	5
		after	**-3.053**	15.642	1.1	**14.543**	1.1	2

The cointegration results of sovereign CDS spreads using Augmented Dickey Fuller (ADF), Johansen Trace, and Max eigenvalue test statistics (with restricted constant) are reported, while the lags are selected by AIC. For the ADF test, critical values are taken from the Mackinnon Critical value. Where the null hypothesis of a unit root is rejected at the 10% of probability, figures are printed in bold. For Johansen trace and max eigenvalue test, the null hypothesis r=0 and r=1 denotes there is no cointegration relation and one cointegration relation respectively. Where the null hypothesis rejected at the 10% level, figures are printed in bold.

Table 46 Cointegration test for Spain's bailout

Event	Variables	Period	ADF	Johansen Trace		Johansen eigenvalue		
			test	r=0	r=1	r=0	r=1	lags
Spain bailout	SP - AT	before	**-2.929**	**19.265**	**8.165**	11.1	**8.165**	5
		after	**-2.759**	**24.41**	**8.267**	**16.142**	**8.267**	7
	SP - BG	before	**-3.286**	15.771	2.8	12.971	2.8	6
		after	**-2.942**	**18.781**	6.014	12.766	6.014	2
	SP - FR	before	**-3.475**	14.974	2.711	12.263	2.711	6
		after	**-3.065**	15.864	3.805	12.059	3.805	2
	SP - DE	before	**-3.23**	15.001	3.746	11.254	3.746	4
		after	-2.135	10.697	2.694	8.003	2.694	2
	SP - UK	before	**-3.409**	12.647	4.466	8.18	4.466	8
		after	-0.801	6.68	2.299	4.381	2.299	5
	SP - GR	before	**-3.163**	15.608	6.787	8.82	6.787	5
		after	-1.571	0	0	0	0	2
	SP - IR	before	-1.543	4.704	1.693	3.011	1.693	5
		after	-2.344	12.731	4.192	8.539	4.192	4
	SP - IT	before	-2.091	6.745	2.291	4.455	2.291	5
		after	**-3.302**	15.065	4.255	10.81	4.255	2
	SP - PT	before	**-3.387**	13.47	3.391	10.079	3.391	4
		after	**-2.79**	15.169	6.399	8.77	6.399	2

The cointegration results of sovereign CDS spreads using Augmented Dickey Fuller (ADF), Johansen Trace, and Max eigenvalue test statistics (with restricted constant) are reported, while the lags are selected by AIC. For the ADF test, critical values are taken from the Mackinnon Critical value. Where the null hypothesis of a unit root is rejected at the 10% of probability, figures are printed in bold. For Johansen trace and max eigenvalue test, the null hypothesis r=0 and r=1 denotes there is no cointegration relation and one cointegration relation respectively. Where the null hypothesis rejected at the 10% level, figures are printed in bold.

Appendix 10

SMP: another policy intervention

There was another form of policy intervention implemented in the wake of sovereign debt crisis: the Securities Market Programme (SMP), which sought to lower the borrowing costs of countries in distress. The creation of the SMP was closely related to the Greek debt crisis, which triggered Europe's wider sovereign debt crisis. This led to a joint EU/IMF/ECB mission. As yields started to rise in Ireland and Portugal, contagion became the overwhelming fear. In an attempt to improve expectations and stabilize markets, European leaders agreed to the creation of the EFSF, on 9 May 2010. This fiscal commitment made intervention a justifiable policy path for the ECB, which announced the creation of the SMP a day later.

The SMP was conducted under the ECB to buy sovereign bonds to "Ensure depth and liquidity in those market segments which are dysfunctional". The plan was to buy those sovereign bonds of those with too low prices (high yields). It was similar to other asset purchasing programmes launched by other major central banks, like quantitative easing (QE). The only and most crucial difference was that ECB 'sterilized' its operations by simultaneously absorbing the same amount of liquidity, to prevent inflation.

There were two rounds of bond purchasing. The first period of intense activity started from 10 May 2010, mainly focusing on the debts of Greece, Ireland and Portugal. This round ended on 9 July 2010. The second period of SMP activism began by holding debt from Ireland, Italy, Portugal and Spain from 18 August 2011. This round ceased on 16 Jan 2012. Eight months later, the programme was terminated by Outright Monetary Transactions (OMTs).

Table 47 Timeline of the SMP during the Eurozone sovereign debt crisis

Date	Event	Average ln CDS spreads in 30 days		
		Country	Before event	After event
Panel A SMP 1st period:　GR, IR, and PT				
10/05/2010	SMP 1st starts	Greece	6.383	6.494
		Ireland	5.084	5.313
		Portugal	5.508	5.615
09/07/2010	SMP 1st ends	Greece	6.728	6.574
		Ireland	5.406	5.291
		Portugal	5.583	5.343
Panel A SMP 2nd period:　IR, IT, PT, and SP				
18/08/2011	SMP 2nd starts	Ireland	6.744	6.718
		Italy	5.595	5.862
		Portugal	6.818	6.936
		Spain	5.678	5.761
16/01/2012	SMP 2nd ends	Ireland	6.505	6.306
		Italy	6.047	5.798
		Portugal	6.987	7.116
		Spain	5.779	5.631

The table presents the list of selected events in the sovereign debt crisis from 2009 to 2013. The average ln-CDS spreads in ±30 days around event date are computed as the average changes across 30 calendar days before and after the event.

The problem with SMP is that data are published only weekly and then only as aggregate values. There is no reference to when during the week they might have been bought. Moreover, the ECB does not provide a breakdown describing the composition of assets by national origin. Therefore, there is a lack of an appropriate approach to compare the different responses across countries, due to the lack of detailed information.

As the table above shows, the two periods of SMP closely match (in date) some of the bailouts. This might cause contamination in the analysis of the impact of bailout.

The results in Figure 27 indicate that the market did not react to the SMP in similar fashion to the bailout plan. The average CDS spreads of Greece, Ireland, Portugal (which are the countries that to ECB buy government bond from in SMP 1st period) were even higher than before intervention, in terms of both the 7-day and the 30-day average. As for the effect of the second period of the SMP, similar reactions are found. Eight months after the second period of the SMP, the program was terminated by Outright Monetary Transactions (OMTs). This indicates the failure of SMP to stabilize the secondary bond market.

Secondly, the ECB’s version of QE is a relatively modest amount ($224bn), which is small compared to other central banks’ QE. Without further supportive measures, ECB purchasing might not be enough for peripheral countries.

Thirdly, the two-stage SMP was generally short-term: the first round lasted 2 months and the second round 5 months. The effects of bailout on the spillover between EU countries are examined over a much longer period.

Therefore, we can suggest that the overall impact of SMP is weak, not strong enough to contaminate the bailout analysis.

Figure 27 Average daily CDS spreads changes around SMP dates

The figure presents the average daily changes of CDS spreads around SMP dates for the following time windows: 30 days before, 7 days before, 7 days after, 30 days after. The countries are selected for their different characteristics and importance to the regional economy, while some were directly affected by the policy intervention.

Appendix 11

This section discusses the specification of CCC, and compares its estimation results of Greece and other 8 countries with the DCC results.

Constant conditional correlation (CCC)

Constant conditional correlation models are based on decomposition of the conditional covariance matrix into conditional standard deviations and correlations. The decomposition comes at a cost: the dynamic structure is lost and more restrictions have to be applied to the multivariate distribution.

Let $r_{it} = (r_{1t}, \dots, r_{it})'$ be the vector of interest, changes in CDS spreads in this case. With random disturbance terms, ε_{it}, time-varying covariance matrix H_t and conditional variance equations of h_t, then:

$$r_t = c_0 + \sum_{i}^{m} \phi_i r_{t-i} + \sum_{i=1}^{n} \phi_j \varepsilon_{t-i} + \varepsilon_t$$

The time-varying covariance matrix, H_t, of constant conditional correlation model (CCC) could be decomposed into

$$H_t = D_t R D_t = \rho_{ij} \sqrt{h_{iit} h_{jjt}}$$

Where D_t is the $(\mathrm{N} \times \mathrm{N})$ diagonal matrix of the time-varying standard deviations from univariate GARCH models with $\sqrt{h_{iit}}$ on the *i* th diagonal; and R is the positive definite constant conditional correlation matrix. The conditional variances and h_{iit} can be estimated and written in the following GARCH(*p*,*q*) model:

$$h_t = \mathrm{c} + \sum_{i}^{q} A_i h_{t-i} + \sum_{i=1}^{p} B_i \varepsilon_{t-i}^2$$

Where $\mathrm{c} \in \mathbb{R}^n$, A_i and B_i are $(\mathrm{N} \times \mathrm{N})$ diagonal matrices. The conditions of the positivity of the covariance matrix, H_t, are that R is positive definite, and the ω and the diagonal matrices A_i and B_i are positive. Then, the log-likelihood at each point in time (LL_t), in the multivariate normal case, be expressed as

$$LL_t = \frac{1}{2}(\log(2\pi) + 2log|D_t|) + log|R| + z_t' R^{-1} z_t'$$

where $z_t' = D_t^{-1}\varepsilon_t$. Thus, Eq (24) includes a term of D_t, for the sum of univariate GARCH model likelihoods, a correlation term, R, and a term for the covariance from the decomposition.

Adopting the same specifications of the ARMA and GARCH models as the DCC approach in the main body, we have the following conditional correlation. The results in Table 48 show the constant conditional correlation between pairwise countries in the EMU. Comparing the magnitude of these correlation coefficients, it can be seen that the co-movements between PIIGS are higher than with the cores. The highest correlation is for the relation between Italy and Spain, at 0.8609, while the lowest is 0.1746, between Austria and Germany. This plotted over time in Figure 28, along with the dynamic correlation for comparison. The blue dotted line represents the hypothesis of a constant correlation.

Table 48 Estimates of constant conditional correlation

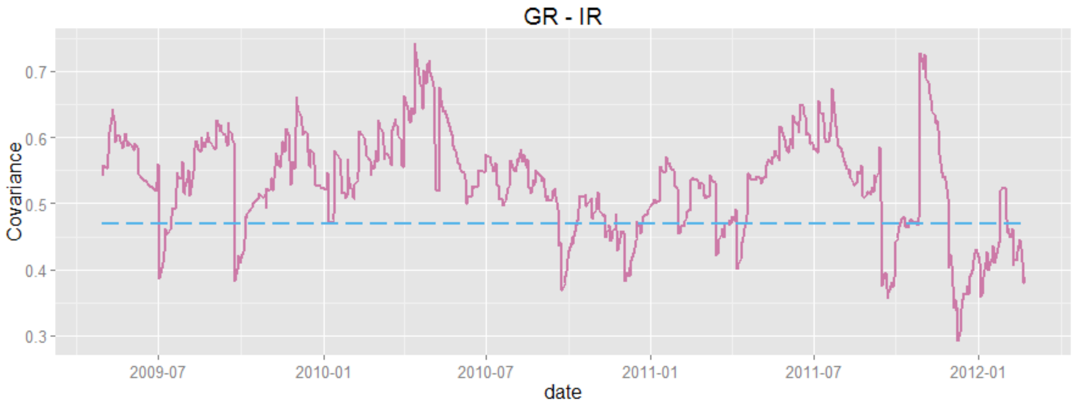
	Austria	Belgium	France	Germany	Greece	Ireland	Italy	Portugal	Spain
Austria	1								
Belgium	0.4195	1							
France	0.2658	0.6063	1						
Germany	0.1746	0.5146	0.5523	1					
Greece	0.2248	0.4432	0.3928	0.3268	1				
Ireland	0.2426	0.5755	0.4568	0.3893	0.4699	1			
Italy	0.3845	0.7419	0.6253	0.5055	0.5188	0.6681	1		
Portugal	0.3181	0.5866	0.5207	0.4514	0.4593	0.6256	0.713	1	
Spain	0.3408	0.7345	0.6169	0.5135	0.4862	0.6628	0.8609	0.7047	1

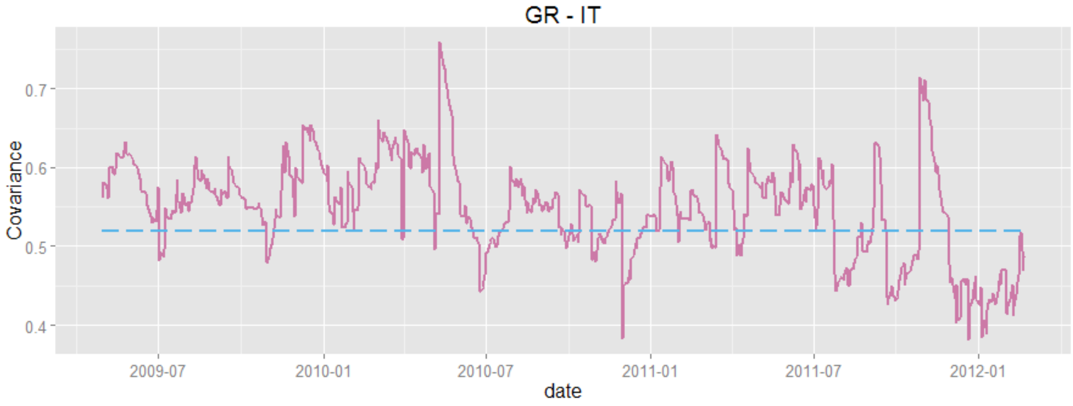
Dynamic conditional correlation (DCC)

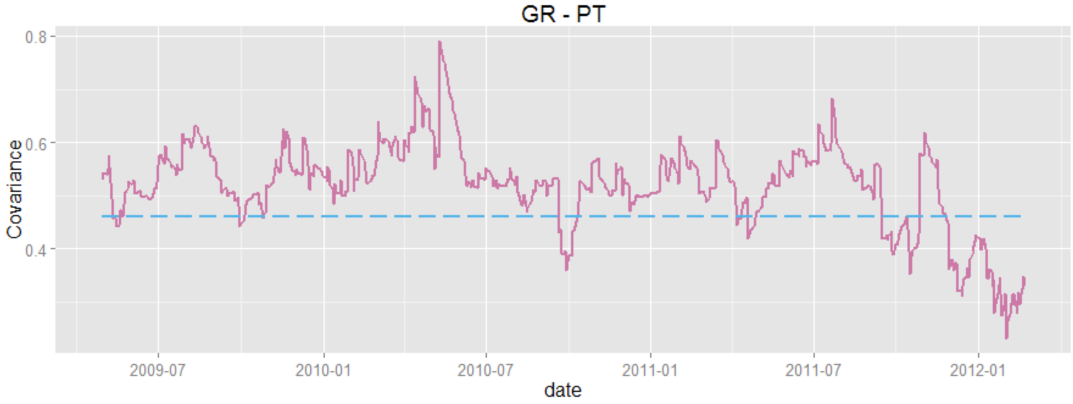
These results examine the correlation between means. The dynamic conditional correlation between Greece and other 8 countries is shown in Figure 28. This figure plots the daily correlation of CDS spread changes between 2009 and 2013. The time-varying red solid line represents the dynamic conditional correlation, which rejects the assumption of constant conditional correlation (CCC). The correlation between Greece sovereign CDS spread and those of other countries exhibits a consistent positive sign, suggesting a same-direction co-movement in the sample period.

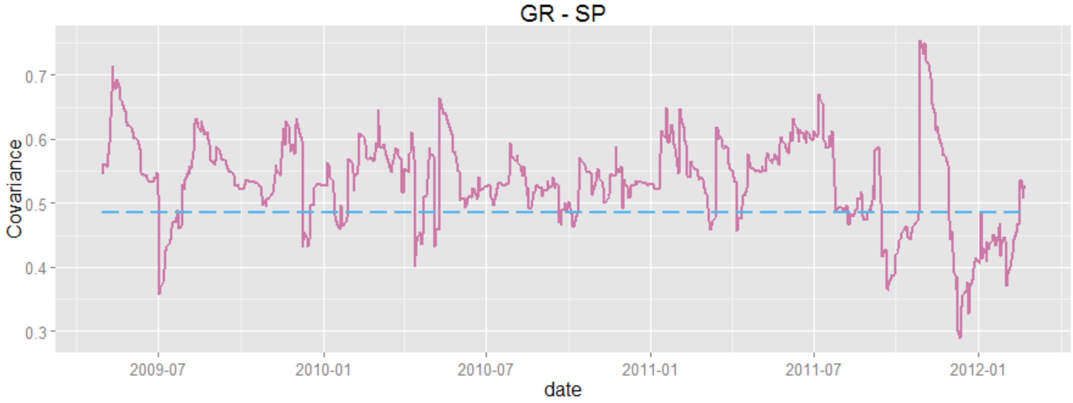
Comparing the fluctuation of the correlations between countries, we find that the correlation between Greece and other PIIGS members are stronger than the links between Greece and the Core countries, while the correlation is generally above 0.5 for the PIIGS and far below 0.5 for the Cores. The result indicates a tight interconnection among the PIIGS members. Among the Core countries, Austria was the least related country to Greece, with an average DCC of 0.3, followed by Germany.

Figure 28 CCC and DCC for Greece









The blue line dotted line represents the constant conditional correlation, while the pink solid represents the dynamic conditional correlation.

Appendix 12

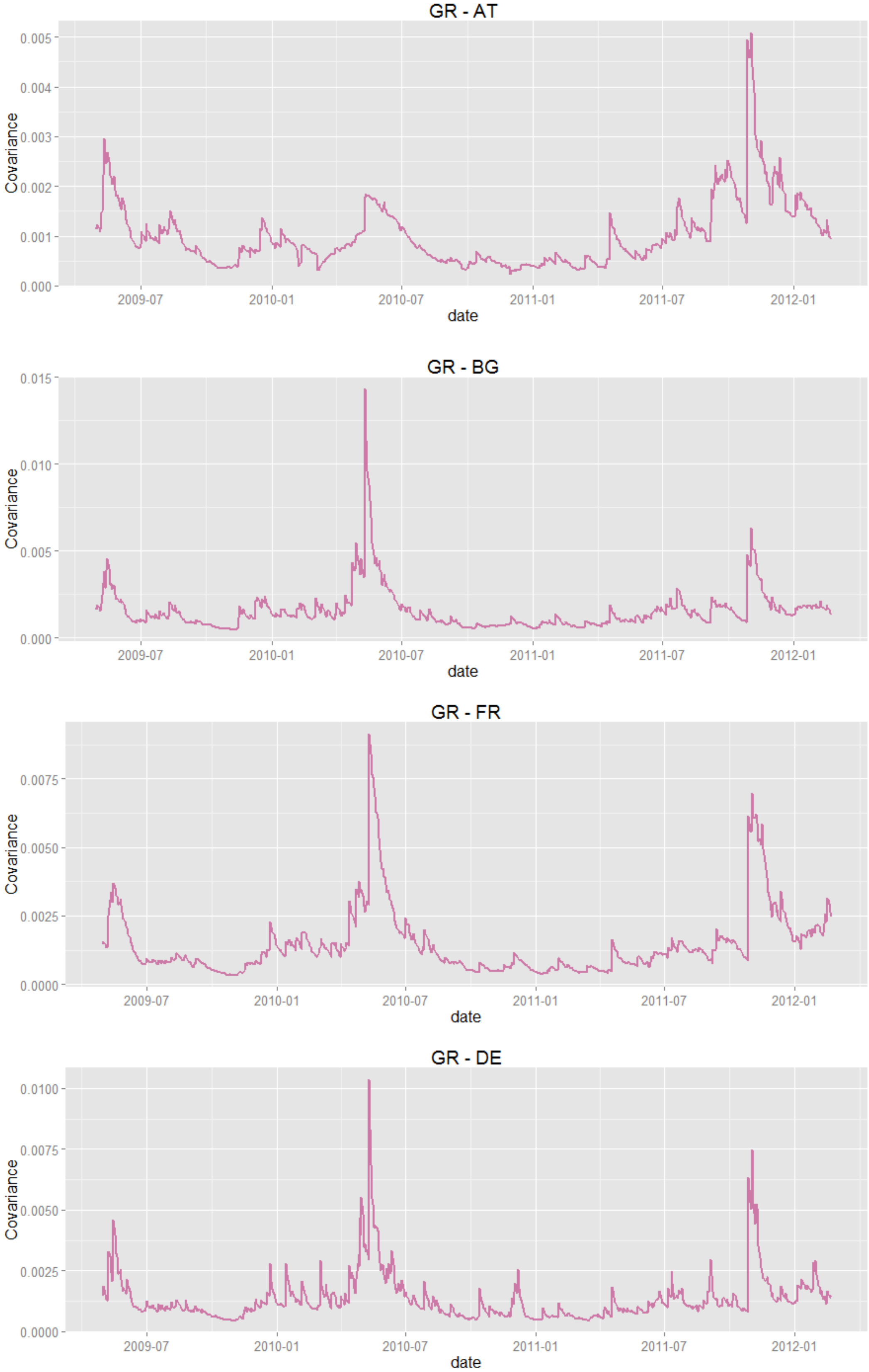
Dynamic conditional covariance analysis

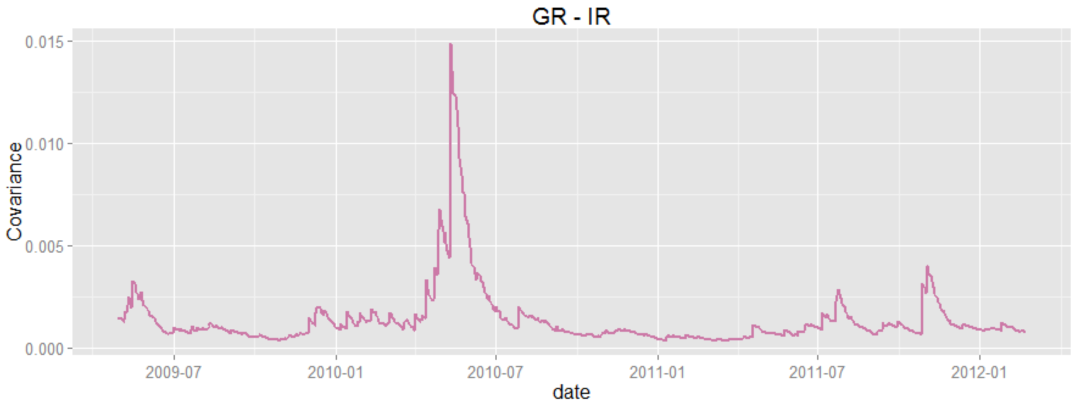
Comparing the pairwise covariances in Figure 29-33, there was a significant pattern for all the bilateral relations. There was significant increase in the covariances around the date of each policy intervention, but they descend rapidly after each intervention. What did differ across the countries were which the specific policy interventions that produced a response in the degree of covariance, and the extent to which they did so. Greece's first bailout and the creation of the EFSF, especially the latter, appear to be the prominent source in influencing the co-movements of these 9 EMU countries. Although Greece's first bailout, Ireland's bailout and the announcement of the ESM did have significant impacts on the covariances, none of the other policy interventions had the same level of impact as the EFSF. This finding highlights the prominent influence of the EFSF on all EMU nations. Moreover, the extent of the response to news about bailouts and the regional rescue fund varied across countries. Our results indicate that the news hit the economically problematic and less politically stable countries harder, that is, had more influence on investor sentiment in relation to these countries.

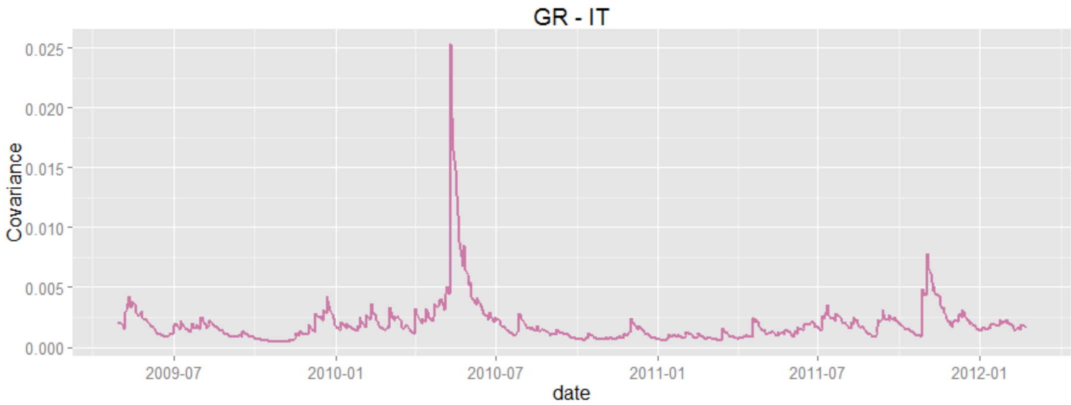
Table 49 Descriptive statistics –covariances

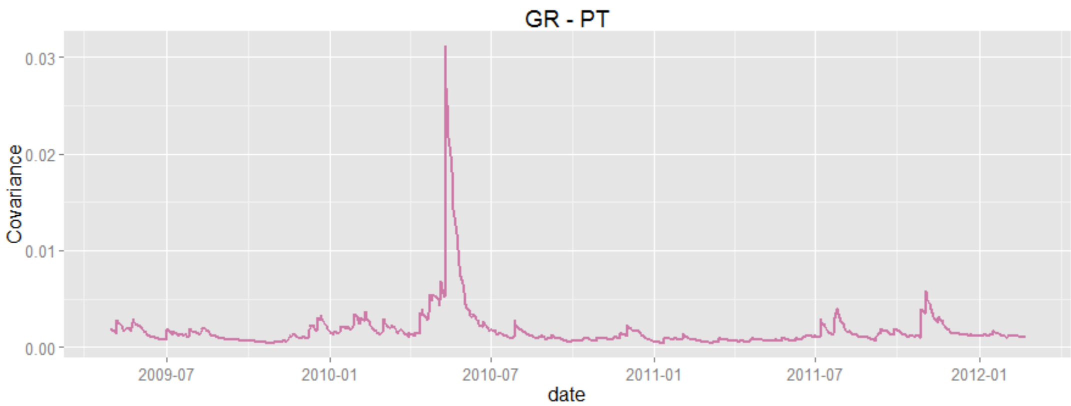
	Min	Max	Mean
Greece			
GR-AT	0.00024	0.00508	0.00101
GR-BG	0.00049	0.01431	0.00158
GR-FR	0.00034	0.00913	0.00146
GR-DE	0.00045	0.01035	0.00135
GR-IR	0.00035	0.01485	0.00136
GR-IT	0.00048	0.02530	0.00194
GR-PT	0.00043	0.03112	0.00176
GR-SP	0.00052	0.01643	0.00182
Ireland			
IR-AT	0.00016	0.00271	0.00070
IR-BG	0.00039	0.01559	0.00136
IR-FR	0.00027	0.00988	0.00114
IR-DE	0.00025	0.01008	0.00116
IR-GR	0.00035	0.01485	0.00136
IR-IT	0.00040	0.02413	0.00165
IR-PT	0.00035	0.02740	0.00155
IR-SP	0.00032	0.01724	0.00159
Italy			
IT-AT	-0.00006	0.00411	0.00120
IT-BG	0.00068	0.01995	0.00222
IT-FR	0.00042	0.01270	0.00182
IT-DE	0.00062	0.01315	0.00170
IT-GR	0.00048	0.02530	0.00194
IT-IR	0.00040	0.02413	0.00165
IT-PT	0.00051	0.03511	0.00209
IT-SP	0.00056	0.02248	0.00262
Portugal			
PT-AT	-0.00062	0.00460	0.00091
PT-BG	0.00048	0.02277	0.00163
PT-FR	0.00032	0.01372	0.00136
PT-DE	0.00043	0.01491	0.00135
PT-GR	0.00043	0.03112	0.00176
PT-IR	0.00035	0.02740	0.00155
PT-IT	0.00051	0.03511	0.00209
PT-SP	0.00043	0.02445	0.00206
Spain			
SP-AT	0.00020	0.00346	0.00117
SP-BG	0.00053	0.01378	0.00206
SP-FR	0.00031	0.00809	0.00176
SP-DE	0.00049	0.00962	0.00167
SP-GR	0.00052	0.01643	0.00182
SP-IR	0.00032	0.01724	0.00159
SP-IT	0.00056	0.02248	0.00262
SP-PT	0.00043	0.02445	0.00206

Figure 29 Covariance dynamics for Greece and other countries




GR - IR
Covariance
0.015
0.010
0.005
0.000
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date


GR - IT
Covariance
0.025
0.020
0.015
0.010
0.005
0.000
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date


GR - PT
Covariance
0.03
0.02
0.01
0.00
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date

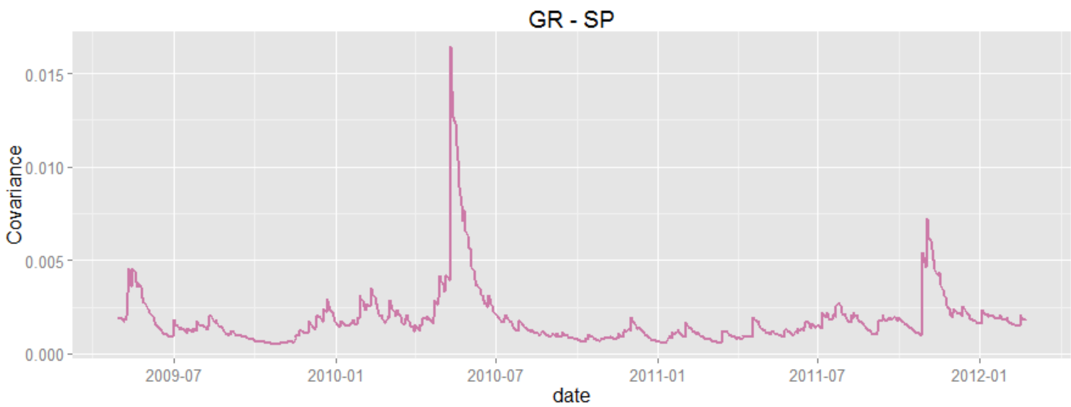
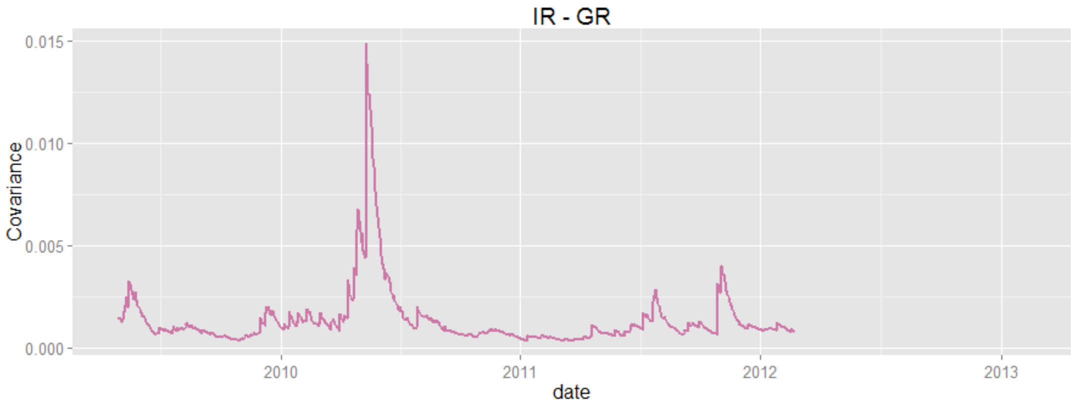
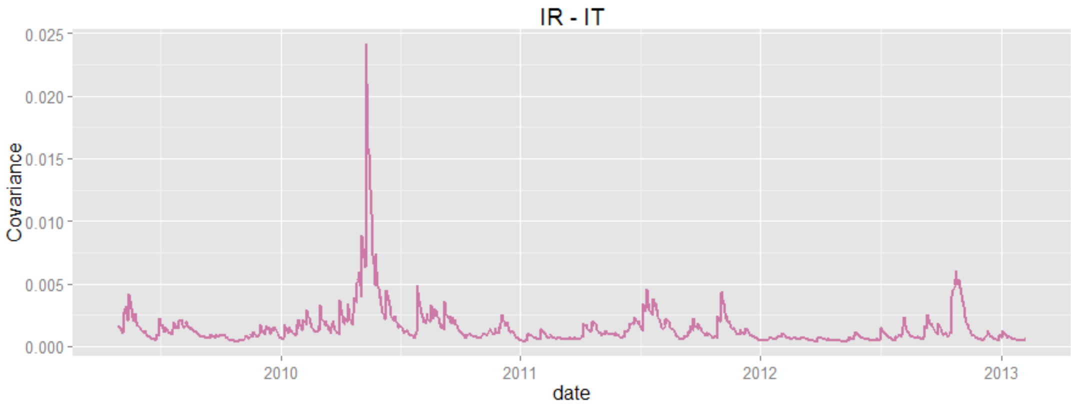
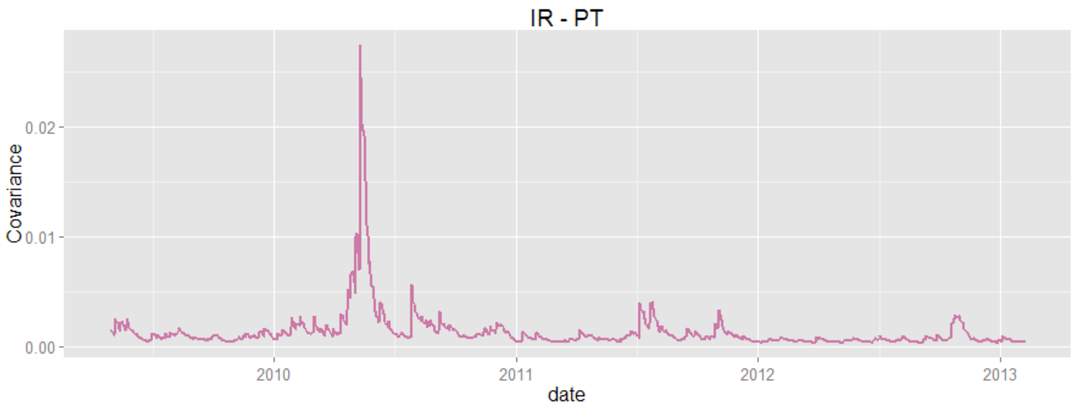

GR - SP
Covariance
0.015
0.010
0.005
0.000
2009-07
2010-01
2010-07
2011-01
2011-07
2012-01
date

Figure 30 Covariance Dynamics for Ireland and other countries


IR - GR
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date


IR - IT
0.025
0.020
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date


IR - PT
0.02
0.01
0.00
Covariance
2010
2011
2012
2013
date

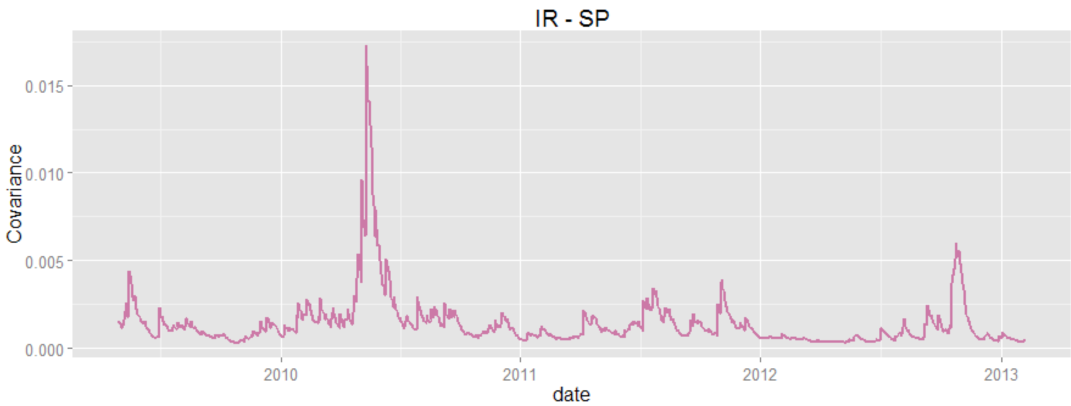
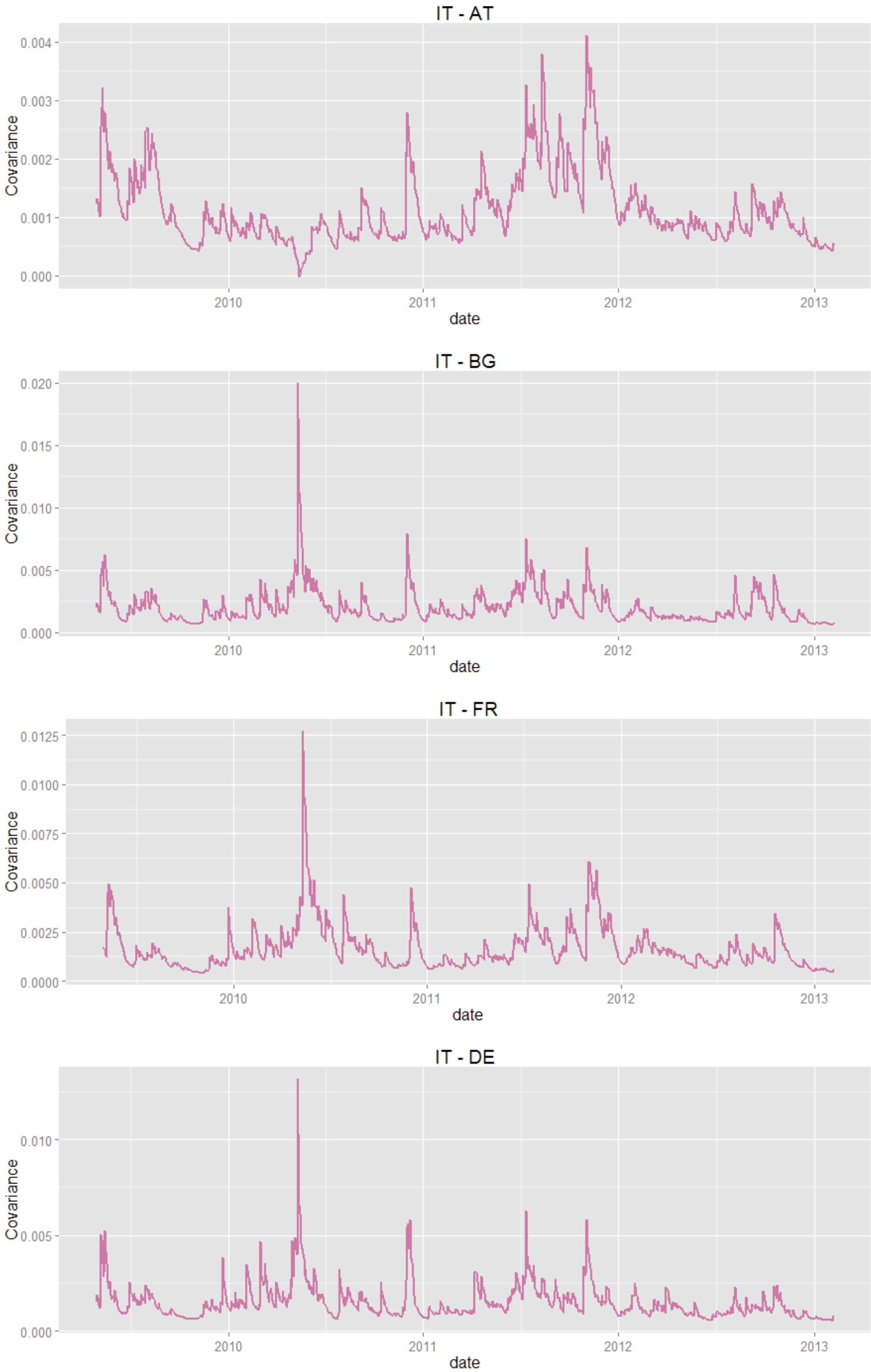
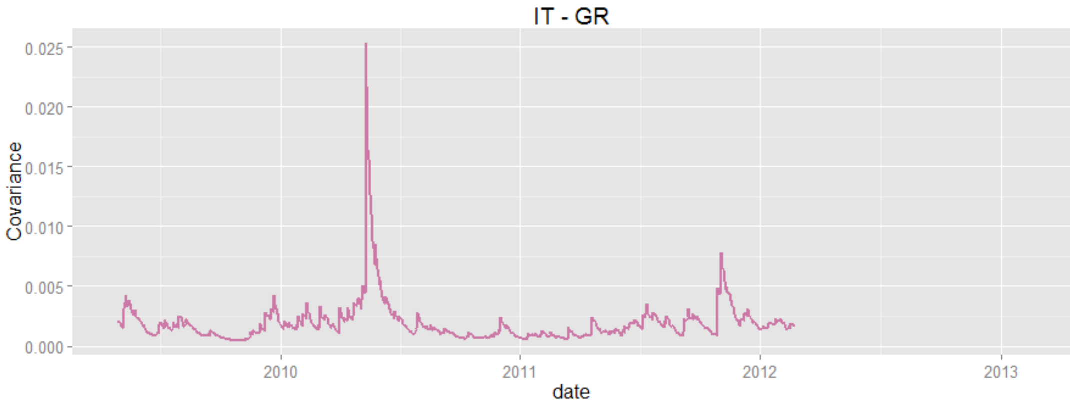
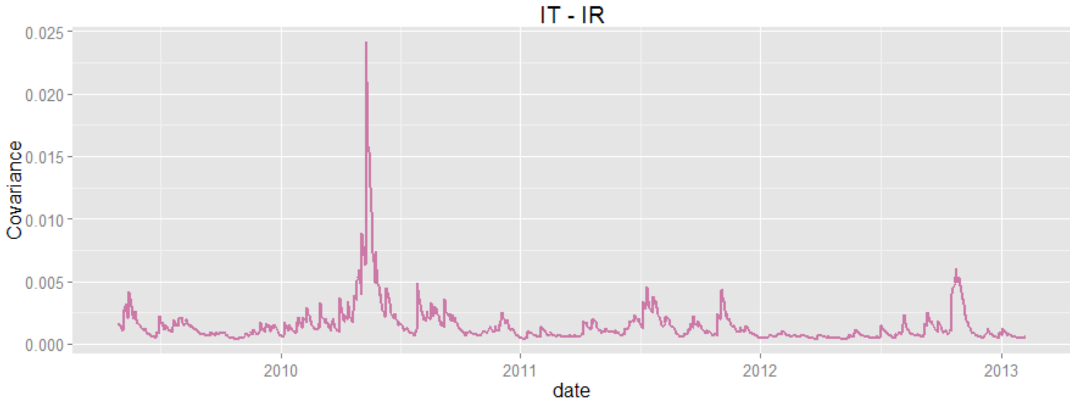
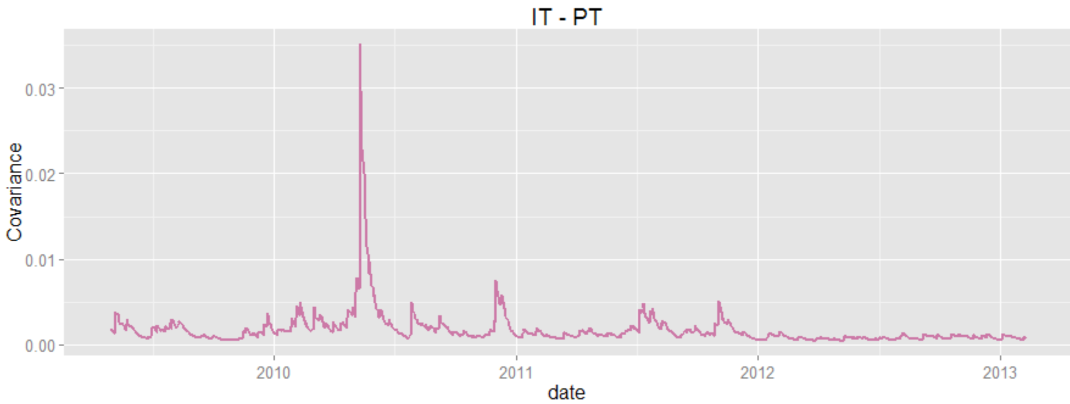

IR - SP
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date

Figure 31 Covariance Dynamics for Italy and other countries




IT - GR
0.025
0.020
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date


IT - IR
0.025
0.020
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date


IT - PT
0.03
0.02
0.01
0.00
Covariance
2010
2011
2012
2013
date

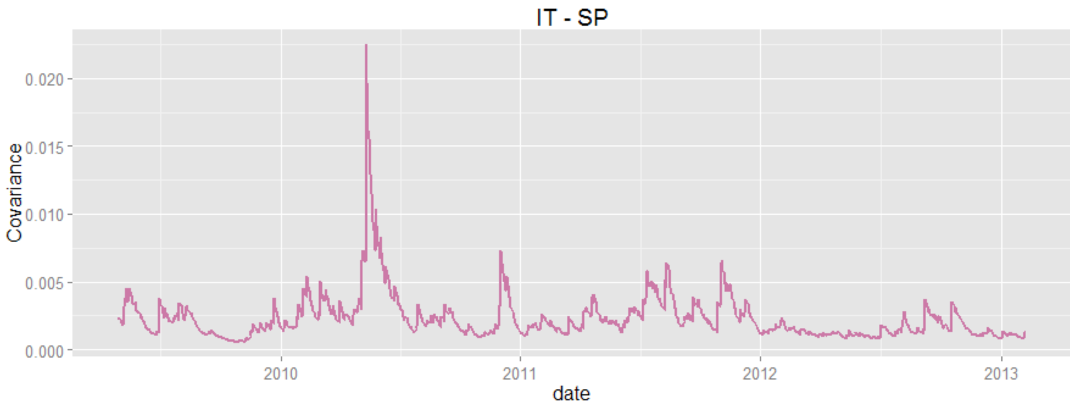
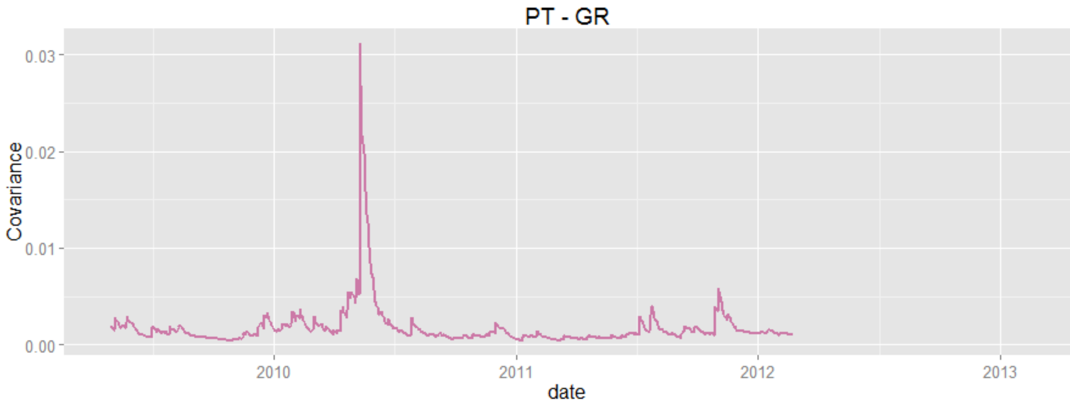
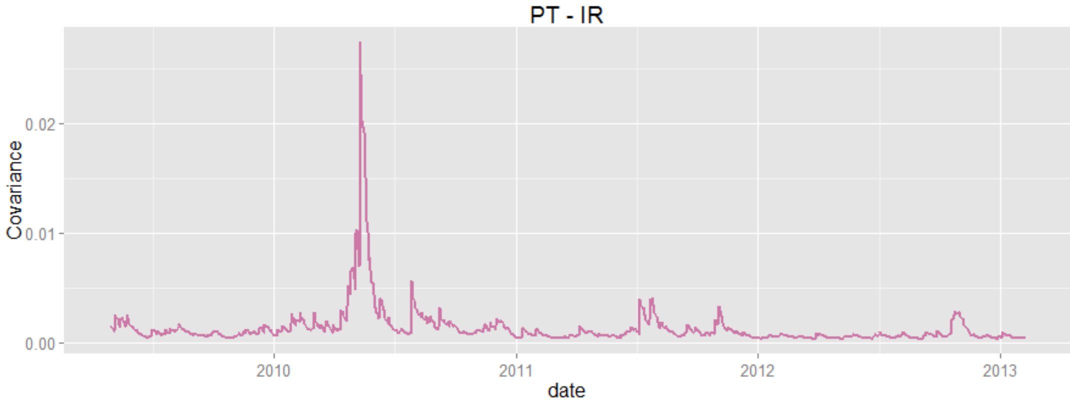
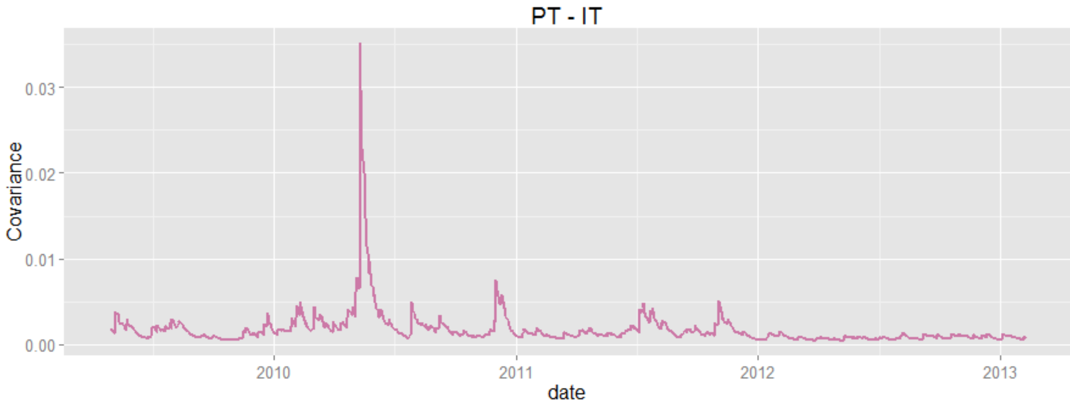

IT - SP
0.020
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date

Figure 32 Covariance Dynamics for Portugal and other countries


PT - GR
Covariance
0.03
0.02
0.01
0.00
2010
2011
2012
2013
date


PT - IR
Covariance
0.02
0.01
0.00
2010
2011
2012
2013
date


PT - IT
Covariance
0.03
0.02
0.01
0.00
2010
2011
2012
2013
date

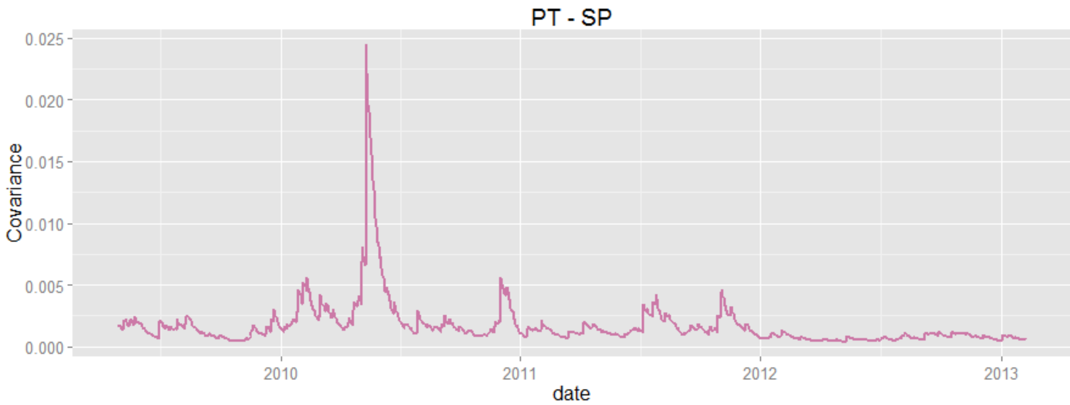

PT - SP
Covariance
0.025
0.020
0.015
0.010
0.005
0.000
2010
2011
2012
2013
date

Figure 33 Covariance Dynamics for Spain and other countries


SP - GR
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date
SP - IR
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date
SP - IT
0.020
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date
SP - PT
0.025
0.020
0.015
0.010
0.005
0.000
Covariance
2010
2011
2012
2013
date

Appendix 13

Detailed summary of policy intervention events during the sovereign debt crisis

EFSF

09/05/2010

EU finance chiefs, in a 14-hour overnight session in Brussels, agree to set up a 750 billion euro rescue mechanism for countries facing financial distress and the ECB says it will buy government and private debt in the biggest attempt yet to end the sovereign debt crisis. The meeting gives birth to the European Financial Stability Facility, the region's temporary bailout mechanism, with initial capital of 440 billion euros. European Financial Stability Facility, or EFSF, was created to provide loans to cash-strapped countries. The EFSF issues bonds that are guaranteed by the euro-area countries. The EFSF also props up foundering banks and other financial institutions through loans to governments.

EFSM

05/01/2011

The European Union creates the European Financial Stabilisation Mechanism (EFSM), an emergency funding programme reliant upon funds raised on the financial markets and guaranteed by the European Commission using the budget of the European Union as collateral.

ESM

11/07/2011

European Stability Mechanism, the permanent bailout fund, is designed to replace the European Financial Stability Facility and the European Financial Stabilisation Mechanism. The new bailout fund is able to lend up to 500 billion euros and is funded by euro-area countries. The original launch date was July 2013, but that was later moved to summer 2012 and then pushed back to launch in late 2012.

19/10/2012

European leaders agree to a single banking supervisor for the Eurozone to be up and running by early 2013. This agreement clears the way for the European Stability Mechanism to directly recapitalize systemically important banks, rather than having to act through national governments.

Greece

12/04/2010

Following worsening financial markets, Euro-area finance ministers agree to provide up to 30 billion euros of emergency loans to Greece over the next year with the IMF agreeing to put up another 15 billion euros in funds.

23/04/2010

Greece Prime Minister, Papandreou, asks EU for a 45 billion-euro bailout from the EU and IMF.

01-02/05/2010

Euro-region agrees on a 110 billion euro rescue package for Greece. Greece agrees to 30 billion euros in austerity cuts over the next three years in exchange for the aid.

21/07/2011

EU summit passes second bailout package for Greece. The EU agrees a comprehensive 109 bn euro package designed to resolve the Greek crisis and prevent contagion among other European economies. Bankers agree to take losses of 21 percent on the net present value of their Greek bond holdings.

27/10/2011

EU leaders hold 14th crisis summit in 21 months. After more than 10 hours of talks, leaders agreed to leverage the EU's temporary bailout fund to boost its firepower to 1 trillion euros, force private investors to accept a 50 percent haircut on Greek bonds, push European banks to raise 106 billion euros in new capital, and extend a new aid package worth 130 billion euros for Greece.

Leaders from the 17 euro-area countries meet in Brussels and agree to write down Greek debt by 50 percent. (In February 2012, the Germans register their opposition to the plan but it's too late – by March, Greek debt is cut by slightly more than half.)

21/02/2012

Euro-area finance ministers reach agreement on the final details of the second bailout package (of 130bn euros) for Greece. The deal includes a 53.5 percent write-down for private investors in Greek bonds.

25/02/2012

Greece formally asks investors to exchange their holdings of government debt for new securities in the biggest sovereign restructuring in history. Two days later, the Greek credit rating is cut to “selective default” by Standard & Poor’s.

On 13 September the second tranche of €6.5bn was disbursed. The third tranche of the same amount was paid on 19 January 2011. On 16 March, the fourth tranche (€10.9 billion) was paid out, followed by the fifth instalment on 2 July. The sixth tranche (€8bn) was paid out after months of delay in early December. Of this amount, the IMF took over €2.2bn.

Ireland

28/11/2010

EU agrees to 85 billion-euro bailout for Ireland.

Ireland reluctantly took a bailout from the IMF, the European Commission and the bailout fund, the EFSF, to the amount of about 85 billion euros. The Irish Republic soon passed the toughest budget in the country's history.

Portugal

16/05/2011

The EU and the IMF approve a 78bn-euro bailout for Portugal.

The deal gave them a three-year loan of up to 78 billion euros from the European Financial Stabilisation Mechanism, the European Financial Stability Facility and the IMF.

Spain

09/06/2012

Spain announces that it will need a 100 bn euro bailout in order to help its failing banks, after it partly nationalizes Bankia SA in May.

By the end of June, EU leaders agreed to ease the terms of Spanish bank loans and paved the way for bond buying by the region’s rescue funds.