University of Reading

Department of Economics

Determinants of Sovereign Credit Risk During and After the European Debt Crisis

Duo Xu

Supervisors:
Alexander Mihailov

James Reade

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STATEMENT OF ORIGINALITY DECLARATION

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Signature: *Duo Xu*

Date: *15 June 2022*

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ABSTRACT OF THE THESIS

This thesis is comprised of three interconnected chapters that critically examine the factors influencing sovereign credit risk determination and the subsequent spillover effects prevalent among peripheral European countries. The research posits, and subsequently confirms, a differential behavior of sovereign credit levels between crisis and non-crisis periods. This observation not only presents nuanced, multidimensional insights on the subject matter but also fills a gap in the existing body of literature.

In the second chapter, an in-depth analysis of the determinants of sovereign bond spreads is undertaken utilizing a dynamic panel regression approach. The study identifies monetary policies, economic fundamentals, and market liquidity as definitive elements influencing a nation's risk level.

Chapter 3 incorporates a vector autoregressive framework to probe the interrelationships and Granger causality between shocks in sovereign credit default swaps spreads and potential determinants. This is a crucial step towards understanding the intricate dynamics between various financial elements and sovereign risk.

Lastly, the thesis delves into the examination of spillover effects among the sovereign credit default swaps spreads of core and peripheral European countries. This discourse offers empirical evidence of sovereign risk contagion and flow among these nations across various phases, including periods of sovereign debt crises, post-crisis recovery, and the COVID-19 pandemic epoch. The study thereby contributes to a deeper comprehension of financial contagion mechanisms and sovereign credit risk behavior in response to macroeconomic shocks and mon-

etary policies.

Chapter 1

INTRODUCTION

This thesis consists of three chapters on the topic of Eurozone countries' sovereign debt levels in crisis and non-crisis periods. By presenting a multifaceted analysis, this work seeks to contribute to the existing body of literature by bridging observed gaps. Chapter 2 explores the determinants of sovereign bond spreads, presenting a comparative analysis of the dynamics before and after the European debt crisis. The study uncovers how both monetary policies and economic fundamentals impact a country's risk level as determined by bond spreads. Chapter 3, then, provides a cogent framework detailing the interrelations and Granger causality among sovereign credit default swaps spreads and potential determinant shocks. Finally, Chapter 4 examines the contagion of sovereign risk among select European periphery and core countries during crisis and non-crisis periods. The following sections present a concise overview of each chapter.

1.1 Chapter 2

Chapter 2 of this thesis probes the determinants of sovereign bond spreads in European periphery countries—Greece, Spain, Portugal, Italy, and Ireland—that bore the brunt of the Global Financial Crisis and the European sovereign debt crisis. These sovereign bond spreads, which serve as a barometer of a country's risk level, are the yield differentials relative to the German government bond, deemed a low-risk and high-liquidity benchmark in Europe.

Higher interest rates generally signal a higher risk of investment, and the behavior of these spreads profoundly influences the economic climate by altering interest rates, especially given the pivotal role European bonds play in the financial market, constituting two-thirds of total outstanding securities. Furthermore, these spreads, which have been seen to morph under different conditions, may reflect a country's government credit rating and consequently affect the overall economic outlook. Remarkably, the reaction of sovereign bond spreads before and after crises, specifically among the PIIGS (Portugal, Ireland, Italy, Greece, and Spain) countries, undergoes a dramatic shift due to the impact of the sovereign credit crisis. This observation underscores the importance of examining the evolution of the determinants of sovereign credit before and after a sovereign crisis, especially given the conservative credit ratings assigned to PIIGS countries by credit rating agencies, which indicates their risk aversion attitudes since the crisis.

The primary objective of this chapter is to explore how potential determinants of sovereign bond spreads, such as market perception, individual countries' economic fundamentals, monetary liquidity, external bailouts, and credit ratings, have changed in the period preceding and succeeding the European debt crisis. To achieve this, we employ a dynamic panel data method as introduced by De Santis (2014) and construct nine regressions for each country to scrutinize the structural composition and verify the robustness of each determinant.

Our dataset spans from Q1 2000 to Q2 2022, partitioned into two sub-periods—pre and post-debt crisis—to distinguish the different determinants operative in each phase. Findings reveal that sovereign bond spreads are more closely correlated to changes in the European overnight deposit rate than to commonly used monetary aggregates. The results also highlight that the post-crisis monetary easing policy significantly curtailed the sovereign risk level of periphery countries. Although the Troika[1] bailouts managed to reduce Greece's risk, they failed to effectively impact Ireland and Portugal's bond spread levels. Contrary to the pre-crisis period when economic fundamentals determined the bond spreads, they become inconsequential post-crisis. This chapter extends past literature by employing an expanded sample period and incorporating macroeconomic and government administrative variables into the model, thus providing a more comprehensive analysis of the determinants of sovereign bond spreads pre and post the European debt crisis.

Our empirical findings hold significant implications for monetary authorities and market participants such as investment banks and hedge funds. Due to the incorporation of macro variables in the model, we employ quarterly data for all variables. Yet, owing to the disparate release dates of the macro variables, the model results' interpretation in this chapter focuses on the long-term impact, sidestepping the immediate impact on secondary market bond spreads. To compensate for this, subsequent chapters utilize higher-frequency data to further delve into the European sovereign credit markets.

[1]Troika: the International Monetary Fund, European Commission, and European Central Bank.

1.2 Chapter 3

Chapter 3 constructs vector autoregressive models to scrutinize in an endogenous econometric set-up employing monthly time series (and, thus, complementing the preceding chapter methodologically as well as in terms of data frequency) the interplay among sovereign credit default swap (CDS) spreads, market liquidity, economic fundamentals, investors' perception, and the European Central Bank's monetary policy's shocks. When Greece's sovereign CDS spreads surged to an unprecedented level, leading to a debt restructuring in 2012 and ultimately, the European debt crisis, Italy, Ireland, Spain, and Portugal bore the brunt of instability via the spillover effects in European financial markets.

Similar to sovereign bond spreads, sovereign CDS offer a direct measure of a country's risk, as a credit derivative traded in secondary markets. While a country theoretically cannot go bankrupt like a corporation, credit events can occur, as evidenced by Greece's debt reconstruction in April 2014. According to Spyrou (2018), the ECB's crisis-era monetary policies significantly deflated the spreads of credit default swaps and bond yields, consequently reducing market uncertainty and investment riskiness across Eurozone countries. However, this conclusion may be model-specific, hence, this chapter explores the impacts of monetary policy across five European periphery countries during and after the crisis.

The central research question we address is: How do ECB monetary policy and other potential determinant shocks affect sovereign CDS spreads in European periphery countries during and after the crisis?

Using monthly data from July 2008 to December 2017, we divide our analysis into two sub-periods: the crisis period (July 2008 to September 2014) and the post-crisis period (October 2014 to December 2017), aligning with Greece's reentry into the sovereign CDS market. We adopt six variables for country-specific models: CDS spreads, bid-ask spreads, VSTOXX index, industrial production, interest rates, and M3. Additionally, a novel application of a vector autoregressive model coupled with artificial neural networks is employed to scrutinize the Granger causality outputs, enabling a non-linear analysis to verify the robustness of the general Granger causality results.

Our findings suggest that shocks to the European stock market do not significantly impact the sovereign credit of the five peripheral European countries. Conversely, the sovereign credit of these countries substantially influences the European stock market. Notably, our research uncovers that the ECB's interest rate reduction policy effectively mitigated the sovereign credit risk of the five peripheral countries during the crisis period. However, in the post-crisis period, this effect was not universal and was only observed in Spain.

In this chapter, we use higher frequency monthly data compared to the quarterly data used in Chapter 2. Despite this, the inclusion of macroeconomic variables leads to the inevitable loss of some financial time series information. Furthermore, the models used here are country-specific, disregarding the spillover effects between countries in sovereign credit markets. To address these limitations, Chapter 4 minimizes the problem of missing information by using daily data on sovereign CDS to investigate the spillover effects among major euro area countries.

1.3 Chapter 4

Chapter 4 delves into the high-frequency contagion relationships of sovereign CDS spreads among nine European nations—core countries (France, the Netherlands, Belgium, and Austria) and periphery countries (Portugal, Spain, Ireland, Italy, and Greece). For years, Greece grappled with balance-of-payments deficits and mounting public debt, culminating in the European sovereign debt crisis. The contagion and spillover effects of escalating sovereign CDS yields left their mark on various European nations, notably Italy, Ireland, Spain, and Portugal. Given their nature as credit derivatives, sovereign CDS spreads are intrinsically sensitive to financial market turmoil. Consequently, our primary research question in this chapter is: How has the spillover effect of the European sovereign credit market evolved from the 2008 economic crisis to the Covid-19 pandemic?

We utilize the directional spillover approach introduced by Diebold and Yilmaz (2012). This method leverages the generalized framework of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998) and produces a variance decomposition invariant to ordering. Our analysis draws on daily data of 5-year maturity sovereign CDS spreads from 15 September 2008 to 30 January 2023, divided into three temporal sub-periods: crisis, post-crisis, and pandemic. This comprises a total of 3,322 observations, enabling high-frequency series analysis, a significant improvement on the data used in Chapters 2 and 3.

The results from our empirical analysis highlight countries with considerable changes in spillover effects over time, notably France, Greece, and Italy. Among the nine target countries in the euro area, Spain and Portugal emerge as primary transmitters of spillover effects in the long run. Furthermore, our analysis reveals that spillovers display varied behavior in different stress environments, with heightened interconnections between individual sovereigns during the Global Financial Crisis and the Eurozone debt crisis compared to the pandemic period. Our research has, in effect, bridged the gap in understanding the spillover effects in sovereign credit markets during the post-crisis period and throughout the pandemic.

Chapter 2

DETERMINANTS OF SOVEREIGN BOND SPREADS BEFORE AND AFTER THE EUROPEAN DEBT CRISIS - EVIDENCE FROM THE PIIGS

Abstract

This chapter analyses the determinants of sovereign bond spreads changes in five European periphery countries before and after the European sovereign debt crisis. In particular, these determinants are associated with changes in market perception and monetary adjustments. The study contains dynamic panel regressions from Q1 2000 to Q2 2022 for Portugal, Spain, Italy, Ireland and Greece. The results indicate market sentiment has been affected by the long-term impact of the European debt crisis, leading to the significant differences in the determinants of bond spreads before and after the crisis, with macroeconomic fundamentals having a greater impact prior to the crisis, while monetary policy has a more significant impact after the crisis.

2.1 Introduction

The Eurozone's sovereign debt crisis began in 2010 when Greece defaulted on its loans from banks, financial institutions, and investment funds, thereby exposing the region to risks that ultimately spread to other countries. While the failure to meet obligations by euro area countries may seem to be the cause of the crisis, it is, in fact, the result of deeper, country-specific fundamental problems, including balance-of-payments deficits and accumulated public debt over several decades, as noted by Gill (2018).

In January 1999, the European Monetary Union (EMU) established a convergence of government bond yields among euro area countries to the level of the German Bund, known as the 'safe haven' for its low risk and high liquidity. However, yield differentials contributed to country-specific credit risk levels. During the European sovereign debt crisis, the euro area sovereign yields exhibited unprecedented volatility, particularly in Greece, Ireland, and Portugal, in contrast to previous spreads across EMU members. European bonds play a crucial role in the financial market, accounting for two-thirds of total outstanding securities, making the movement of sovereign bond yields a significant factor in changing interest rates and influencing investment and consumption decisions. Therefore, in times of crisis, adjusting the sovereign bond spreads becomes necessary. This chapter will focus on Greece, Ireland, Italy, Portugal, and Spain (PIIGS), the five countries that were severely affected by the Global Financial Crisis (GFC) and the European sovereign debt crisis, analyzing sovereign credit changes when they were hit by a debt crisis. For example, the credit ratings of PIIGS countries by credit rating agencies tend to be conservative, reflecting their risk aversion. In this light, it is necessary to study the changes in the determinants of sovereign credit before and after a sovereign crisis.

Previous crises have demonstrated that sovereign bond spreads exhibit various effects. On the one hand, they may reflect a country's government credit rating and impact the overall economic outlook. On the other hand, due to the impact of the sovereign credit crisis, the behavior of national bond spreads before and after crises differs, especially for the five PIIGS countries. Meanwhile, although PIIGS countries share similar euro liquidity following the monetary policies from the European Central Bank (ECB), each countries' diverse economic and government fiscal level would lead to different trends of their sovereign bond spreads. In addition, in response to the European debt crisis, three of the five countries - Greece, Portugal and Ireland - were bailed out by the Troika. Whether the bailouts have long-term positive effects in the sovereign bond market is worth researching and discussing from the perspective of government authorities.

This chapter aims to investigate how potential determinants of sovereign bond spreads have varied across different periods. Specifically, the research seeks to answer questions such as whether bond spreads for countries with varying fiscal and macroeconomic conditions have changed, whether bailouts influenced sovereign bond spreads, and how the determinants of bond spreads changed over time.

Section 2.2 of this chapter reviews the relevant literature on the topic. In Section 2.3 and 2.4, we outline the methodology and benchmark theories used in our analysis, as well as the data sources and descriptive statistics. Our findings are presented in Section 2.5. Finally, we conclude our study in Section 2.6 by summarizing the key results and their implications for future research.

2.2 Literature Review

Sovereign bond spreads in the Euro area are defined as the differences between government bond yields and the German Bund yield, while the sovereign bond spreads in the rest of the world are the differences between their own countries' bonds and US Treasury bonds. This chapter specifically focuses on the differentials between PIIGS countries and German sovereign bond yields. The data on sovereign bond spreads in this chapter are obtained from the secondary market, which is in line with mainstream research. For instance, Scholtens and Tol's (1999) study concluded that secondary market bond spreads better reflect a country's risk than bank loan spreads.

The empirical study on the determinants of sovereign bond spreads can be traced back to Edwards (1986), who identified significant relationships between sovereign-owned bond interest rates and country-specific economic fundamentals in the least developed countries[1]. Barrios et al. (2009)[2] focused on the developments during the GFC that began in 2007 in the Euro area and identified three determinants of yield spreads: credit risk, , risk perception, and liquidity risk. Credit risk is a measure of country-specific risk associated with the probability of government default and can be measured by macroeconomic indices. Credit agencies such as Standard & Poor's, Moody's, and Fitch rate the credit risk of each country, and their sovereign ratings can reflect the risk level and guide investors. Risk perception can be divided into global and domestic concerns, and we will discuss this further in the following section. As the Euro area countries share the same liquidity on monetary policy since the Euro is the common currency in the Eurozone, we exclude the exchange rate effect from our analysis. Instead, the interest rates and monetary aggregate could reflect the overall market liquidity to the

[1] Edwards (1986) also stated that the interest rate charged by the local bank is not associated with the country's risk.

[2] Barrios et al. (2009) also suggest that improvement in global risk perception would narrow the intra-euro bond yield spreads differentials, as discussed further below.

bond yield spreads.

Based on the above research on the determinants of sovereign bond spreads and our research questions, the literature review in this chapter will focus on the following dimensions: domestic and global factors, credit agency ratings, market liquidity, different periods of analysis, and the methodology we choose in this chapter. Previous literature has focused on the impact of specific factors on bond spreads. However, in this chapter, we will combine multiple potential influencing factors to analyze the determinants of bond spreads in different periods.

2.2.1 Global and Domestic Impacts on Sovereign Bond Spreads

In the existing literature, several studies have investigated the relationship between sovereign bond spreads and external factors. Ferrucci (2003) analyzed the monthly data of emerging markets between 1992 and 1998 and found a strong association between markets' sovereign bond spreads and external factors such as global liquidity conditions and the US stock market. However, the study's diagnostic statistics suggested a research limitation due to the lack of randomness, leading to a broad factor based on US equity prices. Gerlach et al. (2010) studied the daily data from 33 primary emerging market spreads worldwide from January 1991 to February 2007 and found a clear correlation between US corporate bond spreads and market debt spreads. Additionally, Barrios et al. (2009) observed that the global financial markets strongly influence the Euro area countries' spreads. The countries' spreads are overall impacted by risk perception, such as corporate bond spreads and stock volatility index. The idea is that investors avoid assets in an insecure environment, especially during crisis periods, as the degree of risk aversion goes up. In the Euro area, capital flows to the German Bund as it is perceived as a "safe haven" both in quality and liquidity during the crisis (Barrios et al., 2009).

Moreover, Arghyrou and Kontonikas (2011) and Favero et al. (2005) confirm that the primary driver of the Euro area government credit spreads is the US stock market implied volatility VIX[3], which is also measured as the global investor's risk perception. It is similar as Longstaff et al. (2011), which confirmed the VIX been part of the determinants of sovereign credit risk. Risk aversion could also be estimated by VIX for the worldwide market and VDAX[4] for the EMU market (Dumicic & Ridzak, 2011). Other indicators of risk aversion include the spread between European (US) AAA corporate bond yields and German Bund (US treasury) rates (Dumicic & Ridzak, 2011) and the differences between the highest and lowest bond spreads among target countries (De Vries & De Haan, 2016). However, to proxy the overall euro-area risk aversion except Germany, VSTOXX[5] is a better index than VDAX as the calculation covers the whole Euro area stock market. Gill (2018) observed that the VSTOXX index was one of the major determinants of the European bond market, which indicates that it can be used to measure investors' perceptions.

A greater volume of literature pertaining to European markets prior to the European debt crisis has presented empirical evidence of the VIX's prominent role as an external influence. After the crisis, Gill (2018) demonstrated the significant impact of fluctuations in European stocks on the bond market. Against this backdrop, the present study employs the VIX and VSTOXX as proxies to gauge investors' perceptions. We posit that there exists a positive correlation between bond spreads and the VIX (or VSTOXX) index, and the significance of these two indices has changed significantly for PIIGS countries before and after the crisis.

The impact of country-specific macro-fundamentals on bond spreads is also a

[3]VIX: Chicago Board of Exchange Market Volatility Index Options
[4]VDAX: Volatility by Deutsche Borse Volatility Index
[5]The VSTOXX Indices are based on EURO STOXX 50.

crucial determinant that, in addition to external financial indicators. Empirical evidence from emerging markets suggests that nations with stronger economic and financial indicators[6] experience lower sensitivity to changes in global financial conditions, measured by the VIX index and US federal funds rate, which are proxies for risk aversion and liquidity patterns (Csonto and Ivaschenko, 2013). Csonto and Ivaschenko (2013) conclude that although country-specific fundamentals are important in the long run, global effects dominate the spread's volatility during the European debt crisis. This result aligns with Comelli's (2012) finding that the coefficient and significance of country-specific fundamentals and external variables can vary across time and nation. Nonetheless, a healthy macroeconomic environment can always help contain bond yield spreads and has more effects in non-crisis times. Dewachter et al. (2014) examine data from Belgium, France, Germany, Italy, and Spain between 2005-2013 and find that economic fundamentals, including inflation, output gap, and central bank policy rates, are the dominant determinants of bond yield rates. However, exogenous shocks, apart from fundamentals, have played a crucial role since the beginning of the sovereign debt crisis in 2011. Favero and Missale (2011) suggest that the Euro area government's fiscal position provides a proxy for bond credit quality, with fiscal deterioration leading to higher risk. This literature (Favero and Missale, 2011) suggests the need for empirical models that account for different time periods. In this chapter, we hypothesize that there exists a negative correlation between macro-fundamentals and sovereign bond spreads, and that this significance will not change significantly before and after the crisis. As mentioned above in line with Comelli (2012), we do not discount the possibility of slight differences in the significance of domestic factors in each country.

[6]Which include GDP per capita, real GDP, inflation, fiscal balance, current account balance, foreign debt, foreign debt service, current account, official reserves, and exchange rate stability.

2.2.2 Credit Ratings and Sovereign Bond Spreads

The credit rating industry plays a vital role in the financial sector, encompassing approximately 150 local and international credit rating agencies worldwide (Langohr and Langohr, 2010). Nevertheless, the market is predominantly dominated by three major players - Standard & Poor's, Moody's, and Fitch, commanding around 40%, 40%, and 15% market share, respectively (Smith and Walter, 2002; White, 2010). Consequently, a significant portion of research in this field relies on data from these dominant agencies. Afonso et al. (2012) have provided empirical evidence supporting the close association between credit rating announcements and fluctuations in bond yields, using data from 1995 to 2010. Their findings demonstrate that the sovereign yield spreads of EU countries respond negatively (and weakly) to the upgrading of EMU countries' credit ratings. Additionally, De Santis (2012) conducted a study investigating the impact of sovereign credit ratings on bond yield rates of EMU countries. The results indicated that credit ratings are linked to yield spreads in Greece, Ireland, Portugal, and Spain, suggesting that credit ratings influence the behavior of market analysts, institutional investors, and banks. This observation unveils a possible interrelationship between sovereign credit bond spreads and credit ratings. During the European debt crisis, higher credit ratings appeared to indicate better economic behavior and lower bond spreads, as evidenced by research conducted by De Vries and De Haan (2016) on the PIIGS. However, their study pointed out a divergence of credit ratings and yield spreads after 2012, attributing it to the monetary policy effect and risk aversion from credit rating agencies. It became evident that bond spreads were no longer in line with the risk assessments of credit rating agencies, as the agencies adopted a more conservative approach. In summary, combining the literature before and after the European debt crisis, it can be hypothesized that credit ratings are negatively correlated with bond spreads - indicating that a better credit rating leads to reduced sovereign risk and subsequently lower bond spreads. Nevertheless, after the crisis, this relationship may become insignificant.

2.2.3 Liquidity Effects on Sovereign Bond Spreads

The liquidity of sovereign bonds is an important determinant of yield spreads in many cases. Pástor and Stambaugh (2003) found that market-wide liquidity is a crucial factor in asset pricing in the US security market by analyzing stock returns. Similarly, sovereign bond spreads may be influenced by market liquidity in the secondary market. Additionally, monetary policies may affect investor behavior in bond trading. The liquidity risk of bonds is significant not only because it generates trading costs, but also because of the random variation over time, which is a source of risk (Favero et al., 2005).

De Santis (2014) uses the difference between German government bond yields and KfW ('Kreditanstalt fur Wiederaufbau') bond yields as an explanatory variable to reflect liquidity and investor preference under the same guarantee. However, the regression output is not significant when he measures liquidity risk as country-specific actual trading volume on the electronic platform MTS in robustness analysis, indicating the weaker effectiveness of this measurement.

Considering the impact of ECB policies on the EMU countries, we use interest rates and M3 volume to measure the liquidity of the European market. Learning from past literature of Euro zone market, M3(Fernández-Amador et al., 2013) and interest rate (Beber et al., 2009) are used a s liquidity variables in this chapter. Higher market liquidity implies lower risk, and we assume a negative correlation between M3 and bond spreads. Moreover, Manganelli and Wolswijk (2009) argue that government bond spreads could be associated with the short-term interest rate, which reflects investor attitude changes. Lower interest rates are correlated with a lower degree of risk aversion and, therefore, lower sovereign bond spreads.

Thus, we hypothesize a positive correlation between the European interest rate and each sovereign bond spread.

2.2.4 Fluctuation of Sovereign Bond Spreads in Different Periods

Numerous studies have highlighted the heterogeneity of sovereign bond spreads across different periods. For instance, Csonto and Ivaschenko (2013) used the pooled mean group estimation approach to examine the movements of emerging market bond spreads over the 2001-2013 period. Their findings suggest that prior to the GFC, most emerging markets, including Euro area countries, experienced significant capital inflows and lower bond spreads. However, during the crisis, the imbalanced macroeconomic conditions of European emerging markets led to sharp increases in bond spreads following the halt of capital inflows. Similarly, Tebaldi et al. (2018), using time dummies, revealed that the sovereign bond spreads of emerging markets were negatively affected by the 1997-1998 and 2008-2009 crises. Similarly, in the study of Euro area, the impact of crisis pressure on sovereign bond spreads was proved through change of liquidity risks (Aβmann and Boysen-Hogrefe, 2012). While most of the previous literature has focused on comparing changes in sovereign bond spreads between crisis and non-crisis periods, it is believed that the European sovereign debt crisis has changed investors' perceptions of sovereign credit, particularly for the countries most severely affected by the crisis. Therefore, this chapter aims to investigate the determinants of sovereign bond spreads over periods before and after the crisis to account for their variations.

2.2.5 Methodological Approaches on Determinants of Sovereign Bond Spreads

The theoretical framework that assumes risk-neutral lenders and competitive financial markets in an indebted small open economy was first proposed by Edwards (1986). However, most empirical research on bond spreads has been based on regression analysis. Hallerberg and Wolff (2008) found that bond spreads are autocorrelated by applying a Hausman test and that the lagged dependent variable is highly significant when included in all models. This indicates that the persistence of spreads implies that excluding the lagged spread term from the model would generate omitted variable bias. However, including lagged terms would lead to a different bias due to its correlation with the fixed effects (Nickell, 1981). The second bias declines as the time-series dimension of the panel (T) increases and becomes relatively small once T reaches 20 (Beck and Katz, 2004). The dynamic panel approach, which contains both bond spreads and their lagged value, was applied in De Santis (2014) and Tebaldi et al.'s (2018) research. In this chapter, we will continue to use the dynamic panel model. First, our sample size is above 80, which effectively avoids the result deviation caused by autocorrelation. Secondly, the dynamic panel model can include multiple independent variables, and it has been proven effective in the study of bond spreads. Unlike previous literature, we will analyze a higher dimension of determinants of sovereign bond spreads in this chapter.

The impact of monetary policies, including changes in interest rates and monetary aggregates from the ECB, on the bond spreads of periphery European countries is not well understood prior to this study. This chapter aims to analyze the uniformity and heterogeneity of the determinants of sovereign bond spreads before and after the European sovereign debt crisis, as the crisis affected countries' risk perceptions. In contrast to past literature, this study includes a broader sample, encompassing four crisis and two non-crisis periods. Furthermore, while much research on sovereign bond spreads has used high-frequency data, this study employs quarterly data and covers a period of 22 years, making it the first empirical investigation of how macro-fundamentals affect sovereign bond spreads over a long term.

Table 2.1: Potential Determinants of Sovereign Bond Spreads with Reference

Potential determinants	Authors	Hypothetic correlation sign with sovereign bond spreads
External stock index	Ferrucci (2003), Gerlach et al. (2010), Barrios et al. (2009)	+
Interest rate	Manganelli and Wolswijk (2009)	+
Economic fundamentals	Commelli (2012), Csonto and Ivaschenko (2013), Dewachter et al. (2014)	-
Credit ratings	De Santis (2012), De Vries and De Haan (2016), Afonso et al. (2011)	-
Market liquidity	Pastor and Stambaugh (2003), Favero et al. (2005), De Santis (2014), Gomez-Puig (2006)	-

Note: This table presents the potential determinants of sovereign bond spreads with evidences of references. The symbol '+' means there are positive correlations between the determinant and sovereign bond spreads; and the symbol '-' means there are negative correlations between the determinant and sovereign bond spreads.

2.3 Methodology

The pricing model of sovereign bond spreads was first introduced by Edwards (1986) which utilizes a risk premium framework and default probability discussion with a risk-free rate. This framework assumes a competitive financial market and risk-neutral investors. In this paper, European sovereign bond spreads are based on the German Bund, which is considered to be the most stable and reliable sovereign bond in the EMU. The proposed analysis framework simultaneously captures and extends the insights of previous studies by Arghyrou and Kontonikas (2011), Afonso et al. (2011), and De Santis (2012). The specification to assess the potential determinants of sovereign long-term bond yields can be expressed as a dynamic panel approach as follows:

$$\begin{aligned} B_{i,t} - B_{b,t} = \beta_{1,i} + \beta_{2,i}(B_{i,t-1} - B_{b,t-1}) + \beta_{3,i} I_{Euro,i} + \beta_{4,i} L_{Euro,i} + \beta_{5,i} C_{i,t} \\ + \beta_{6,i} dummy_1 M_{i,t} + \beta_{7,i} dummy_{2,i} T_{i,t} + \beta_{8,i} dummy_3 + u_{i,t} \end{aligned} \tag{2.1}$$

Where $B_{i,t} - B_{b,t}$ denotes the spread between the government bond yield in country i and the benchmark country - German's Bund rate. $I_{Euro,i}$ indicates the European investors perception in financial market, known as the volatility risk premium which was confirmed to be related to sovereign credit spreads in Longstaff et al. (2011). $L_{Euro,i}$ determines the bond liquidity condition among Euro countries, which measured by monetary policies of European Central Bank (ECB). $C_{i,t}$ is the credit ratings from major credit agencies. $M_{i,t}$ includes macroeconomic variables in different countries i. $T_{i,t}$ is a dummy variable that denotes a bailout received by country i from the Troika. $\beta_{1,i}$ includes all exogenous components of bond spreads' determinants. $dummy_3$ is a dummy variable of crisis periods when the VIX index is sustaining above 20.

To capture the determinants of sovereign bond spreads, this study employs a dynamic panel approach, following the methodology of previous research by Hallerberg and Wolff (2008), De Santis (2014), and Tebaldi et al. (2018). The independent variables in the analysis include both country-specific and global factors, as previous studies have highlighted the relevance of external factors in shaping the country risk premia. As sovereign bond spreads may be influenced by their past values, lagged bond yields are included in all regressions. The sample consists of 90 observations covering four crisis and two non-crisis periods, and the analysis focuses on the European sovereign bond spreads based on the German Bund, which is considered the most reliable benchmark in the Eurozone. To test the sensitivity of the results, we also estimate regressions without the lagged bond yields, as suggested by Hallerberg and Wolff (2008), to investigate any potential bias arising from omitted lagged variables.

The liquidity variables in this study are quantified by ECB's overnight deposit rates and M3 growth rate, in accordance with previous studies by Beber et al. (2009) and Fernandez-Amador et al. (2013). The ECB interest rate, which is one of the monetary policy measurements in this chapter, is set by the European Central Bank for the Eurozone and comprises three key interest rates: the main refinancing operations rates, deposit facility rates, and lending facility rates. The sample consists of Ireland, Italy, Portugal, Spain, and Greece, which entered the Eurozone between 1999 and 2001. The overnight deposit rates are used as an indicator of European monetary policy. Another proxy of monetary adjustment is M3, which refers to the authorities' market money issuing amount. M3 includes all local currency in circulation, such as demand deposits, large saving deposits, and other less liquid components of the money supply, in addition to M2. M2 contains money in circulation plus checkable deposits in banks (M1), small savings, and money market mutual funds.

In addition to country-specific variables, this study also considers world and European-wide variables that capture global investor risk perception. The CBOE[7] volatility index (VIX), commonly known as the US stock market fear index, is used as a measure of global investor risk perception, following previous studies such as Arghyrou and Kontonikas (2011), Favero et al. (2005), Beber et al. (2009), and Gerlach et al. (2010). Another variable used to capture risk perception is the Euro Stoxx 50 index (VSTOXX), which represents the most significant super-sector leaders in the Eurozone based on free-float market capitalization. Gill (2018) has confirmed the VSTOXX's dominance in the European market. These variables allow for a more comprehensive analysis of the factors that contribute to sovereign bond spreads.

To control for the impact of global risk on our research variables, we introduce a dummy variable, "high global risk level", to the model. It is widely recognized that the U.S. stock market can have a significant impact on the credit rating of the global bond market. In line with previous studies (e.g., Arghyrou and Kontonikas, 2011; Favero et al., 2005; Beber et al., 2009), we use the VIX index as a measure of global investor risk perception. When the VIX exceeds 20, we set the dummy variable to 1, representing high global risk. By including this variable, we aim to better control for external factors that could affect PIIGS bond spreads, and to more accurately assess the impact of the U.S. stock market on the creditworthiness of peripheral European countries.

The proposed model includes country-specific components such as credit ratings, macroeconomic variables, and bailouts received from the Troika.

Credit ratings from three primary rating agencies, namely Standard & Poor,

[7]CBOE: Chicago Board Options Exchange.

Moody's, and Fitch, are included in the model. The close relationship between credit rating announcements and bond yield fluctuation is confirmed by Afonso et al. (2012)[8]. The ratings are quantified by using the rating system provided by Afonso et al. (2012), with the credit ratings from Standard & Poor used in the benchmark model, while the other two ratings are discussed in the robustness analysis.

The model also considers two macroeconomic variables, namely the budget surplus/deficit to GDP ratio and the quarterly GDP growth rate. The government's fiscal position is widely accepted as a proxy for bond credit quality (Favero & Missale, 2011), and macro fundamentals are known to have a significant impact on bond spreads (Comelli, 2012). Real GDP growth rate and budget balance for each country are included in Regressions V and VII.

During the European debt crisis, Greece, Portugal, and Ireland received international bailout programs monitored by the Troika, composed of representatives from the European Commission, Europe Central Bank, and International Monetary Fund. The bailouts aimed to alleviate the economic recession and mitigate the behavior in financial markets, which potentially benefited sovereign risks. Dummy variables are created and equal to 1 during the bailout period, and the bailout factor is included in Regressions VI and VII for Greece, Portugal, and Ireland models.

The sample period for our analysis covers quarterly data from 2000 to 2022. To account for the potential effects of the Greek government credit default, we divided the sample into two sub-periods, namely pre- and post-European debt crisis. The first sub-period spans from Q1 2000 to Q4 2009, covering two crisis periods - early 2000s crisis and the great financial crisis. The second sub-period runs from

[8]They also establish a bi-directional causality between ratings and bond spreads.

Q1 2010 to Q2 2022, consisting of two crisis periods - the European sovereign debt crisis and COVID-19 pandemic crisis. The European sovereign debt crisis, which commenced in 2009, prompted authorities to initiate large-scale, multi-year assistance to certain countries in early 2010, marking a departure from their wait-and-see approach. Before 2009, the credit outlook for European countries in the market may have undergone structural changes following the crisis. The dummy variable of "high global risk perception" is used to differentiate between the crisis and non-crisis periods and to examine the effects of country-specific and global factors on bond spreads over time.

2.4 Descriptive Statistics

The dataset used in this study consists of quarterly frequency data spanning from the first quarter of 2000 to the second quarter of 2022. The macroeconomic variables and sovereign bond yields data were obtained from the Federal Reserve Bank of St. Louis and Thomson Reuters Terminal, respectively. The GDPs of the five countries were seasonally adjusted using an ARIMA approach. The credit ratings data were sourced from the official websites of the three rating agencies, and their qualification measurement followed Afonso et al. (2012) (see Appendix A). Additionally, government budget balance data were downloaded from Eurostat.

Table A1 (in Appendix A) presents the descriptive statistics of the entire sample, while Figure 2.1 shows the fluctuation of VIX and VSTOXX from 2000 to 2022. The general trend of the two indices is similar. Figure 2.1 reveals four crisis periods of higher index values: the early 2000s recession, the great recession, the European debt crisis, and the COVID-19 pandemic. The overall value of VSTOXX is larger than VIX, as evidenced by their mean, median, maximum, and minimum values from Table A1, indicating that investors perceive the European stock market as riskier than the US market. Moreover, the fluctuations of the VIX and VSTOXX indexes before the crisis are more pronounced than after the crisis. At the same time, we also calculate the pairwise correlation among the variables (in Appendix A). We avoid using high correlation[9] variables in the one regression[10].

In our sample, the median value of overall deposit rates from the ECB is 1, indicating a low level of interest rates over a long period. Before the crisis, the mean of interest rates was 3.89, which is significantly different from the mean value of

[9] Correlation ≥ 0.7.

[10] When there are interrelated variables in the designed regression, we drop one of them as a robustness test.

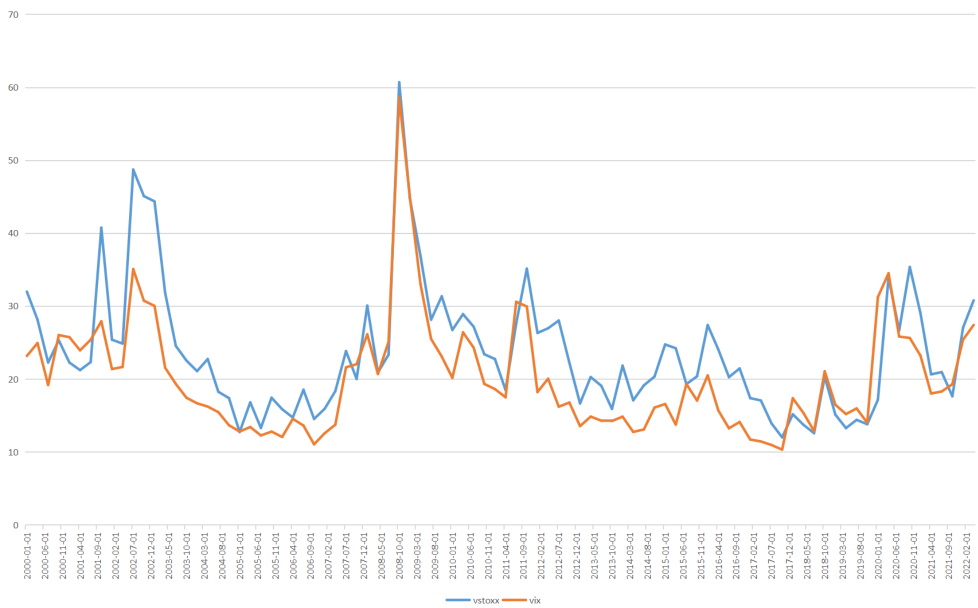
0.35 after the crisis. The average bond spreads in Greece reached 7.09 after the crisis, followed by Portugal (3.11) and Italy (2.01), while the mean value of bond spreads in each country before the crisis was less than 0.6. Moreover, the standard deviation of the sovereign bond spreads of PIIGS countries after the crisis is greater than before the crisis. These data demonstrate the significant changes in bond spreads of PIIGS countries before and after the crisis intuitively.

Regarding GDP growth rate, Spain suffered the most, with a minimum value of -17.46, while Ireland had the highest minimum value of -4.44. Irish GDP experienced the highest growth rate of 23.29% in the first quarter of 2015, and the Greek GDP had the slowest increase, even with a high growth rate of 6.54% compared to the last quarter. Figure A1 (in Appendix A) shows a coinstantaneous GDP negative growth rate of five countries in 2008, 2011, and 2012, and Irish GDP growth experienced tremendous volatility after 2014. All countries experienced negative growth rates in late 2019 and early 2020 due to the impacts of COVID-19, followed by a considerable rebound. Overall, GDP growth fluctuated more after the crisis than before. The budget deficit data, which as another macro-fundamental variable in our model, revealed that before and after the crisis, the five countries had a fiscal deficit on average, with standard deviation maintained at a relatively high level.

The credit ratings of all five countries show very similar trends, and there are marginal differences among the three credit agencies' ratings. Figure A2 (in Appendix A) demonstrates that Standard & Poor's has the quickest response to a potential downgrading trend, and its ratings are the least sensitive to an upgrading, which reveals its conservative character. After the crisis, the credit ratings of all countries were lower than those before the crisis. Compared to the flat and stable ratings before the crisis, the fluctuations in the credit ratings of various countries after the crisis are more obvious.

The observations made in this study reveal that the European sovereign debt crisis has had a significant impact on various economic indicators. The noticeable changes in the bond spreads of the PIIGS countries can be attributed to investors' increased risk awareness after the crisis. There is similarity in volatility trends between the VIX index and the VSTOXX index, but greater volatility before the European debt crisis than after that. Furthermore, the post-crisis GDP growth rates have exhibited considerable fluctuation, which may be due to the crisis's long-term effects on the economies of the analyzed countries. Lastly, credit ratings for all countries have declined after the crisis, indicating that the crisis had a lasting impact on their creditworthiness. These findings offer valuable insights into the crisis's long-term impact on the determination of sovereign bond spreads of countries located on the periphery of Europe.

Figure 2.1: Comparison Between VIX and VSTOXX Indice



Note: This figure presnets the fear indice in the US stock market (VIX) and the European stock market(VSTOXX); the y-axis represents the index value of VIX and VSTOXX.
Source: Thomson Reuters Datastream.

Table 2.2: Descriptive Statistics of Before-crisis Sample

Before Crisis	VSTOXX	VIX	ECB RATES	M3 GROWTH RATE		
Mean	25.9688	22.1168	3.8938	1.7771		
Median	22.6250	21.5602	4.2500	1.8184		
Maximum	60.6800	58.5878	4.2500	4.2447		
Minimum	12.7200	11.0349	1.0000	-0.8146		
Standard Dev.	10.8971	9.4528	0.9127	1.0656		
Skewness	1.3575	1.7900	-2.5924	-0.3966		
Kurtosis	1.6330	4.9385	5.5114	0.3202		
Observations	40	40	40	40		
	GREECE BOND SPREADS	GDP GROWTH RATE - GREECE	BUDGET DEFICIT - GREECE	S&P - GREECE	MOODY'S - GREECE	FITCH - GREECE
Mean	0.5695	0.6095	-7.6525	11.9250	12.7000	11.8750
Median	0.3307	0.4824	-6.8500	12.0000	13.0000	12.0000
Maximum	2.6507	4.3319	1.7000	13.0000	13.0000	13.0000
Minimum	0.1520	-4.2924	-16.6000	10.0000	12.0000	10.0000
Standard Dev.	0.5595	1.7258	4.5559	0.6558	0.4641	0.6864
Skewness	2.2464	-0.1689	-0.2509	-0.4984	-0.9073	-1.3379
Kurtosis	4.9753	0.6156	-0.5857	1.0984	-1.2416	2.8515
Observations	40	40	40	40	40	40
	IRELAND BOND SPREADS	GDP GROWTH RATE - IRELAND	BUDGET DEFICIT - IRELAND	S&P - IRELAND	MOODY'S - IRELAND	FITCH - IRELAND
Mean	0.3400	0.7997	-1.9094	16.6750	16.9500	16.9000
Median	0.1833	0.8177	-0.8500	17.0000	17.0000	17.0000
Maximum	2.4640	5.4741	8.8000	17.0000	17.0000	17.0000
Minimum	-0.0383	-4.0851	-18.7000	15.0000	16.0000	15.0000
Standard Dev.	0.6011	2.1496	6.0852	0.6155	0.2207	0.3789
Skewness	2.5095	0.0211	-1.0457	-1.7618	-4.2921	-4.1073
Kurtosis	5.4907	0.0597	1.1267	2.0481	17.2853	17.5678
Observations	40	40	32	40	40	40
	ITALY BOND SPREADS	GDP GROWTH RATE - ITALY	BUDGET DEFICIT - ITALY	S&P - ITALY	MOODY'S - ITALY	FITCH - ITALY
Mean	0.3892	0.1001	-3.3850	14.1250	15.0000	14.4500
Median	0.2691	0.1979	-1.7000	14.0000	15.0000	14.0000
Maximum	1.4658	1.6019	3.8000	15.0000	15.0000	15.0000
Minimum	0.1407	-2.5902	-12.2000	13.0000	15.0000	14.0000
Standard Dev.	0.3022	0.9323	4.4520	0.8825	0.0000	0.5038
Skewness	2.2147	-1.0413	-0.6756	-0.2540	/	0.2089
Kurtosis	4.4985	1.4672	-0.6840	-1.6983	/	-2.0622
Observations	40	40	40	40	40	40
	PORTUGAL BOND SPREADS	GDP GROWTH RATE - PORTUGAL	BUDGET DEFICIT - PORTUGAL	S&P - PORTUGAL	MOODY'S - PORTUGAL	FITCH - PORTUGAL
Mean	0.3092	0.2238	-4.9500	14.4250	15.0000	15.0000
Median	0.2311	0.2917	-4.9500	15.0000	15.0000	15.0000
Maximum	1.4340	2.2568	-0.5000	15.0000	15.0000	15.0000
Minimum	0.0017	-2.2344	-13.8000	13.0000	15.0000	15.0000
Standard Dev.	0.2910	0.9129	3.1376	0.6751	0.0000	0.0000
Skewness	2.2475	-0.2186	-0.6779	-0.7661	/	/
Kurtosis	5.8071	0.4021	0.2425	-0.4696	/	/
Observations	40	40	40	40	40	40
	SPAIN BOND SPREADS	GDP GROWTH RATE - SPAIN	BUDGET DEFICIT - SPAIN	S&P - SPAIN	MOODY'S - SPAIN	FITCH - SPAIN
Mean	0.2147	0.6039	-1.2275	16.4250	16.6500	16.6250
Median	0.1287	0.7457	-0.8000	16.0000	17.0000	17.0000
Maximum	1.0734	1.6280	7.7000	17.0000	17.0000	17.0000
Minimum	0.0104	-2.4924	-16.4000	16.0000	15.0000	16.0000
Standard Dev.	0.2353	0.7619	4.9135	0.5006	0.7696	0.4903
Skewness	1.8862	-2.2249	-1.2007	0.3154	-1.7781	-0.5367
Kurtosis	3.9241	6.7262	2.2722	-2.0034	1.2200	-1.8048
Observations	40	40	40	40	40	40

Note: This table presents the descriptive statistics before the European debt crisis, i.e., from Q1 2000 to Q4 2009. The descriptive statistics are rounded to four decimal places.
Source: Thomson Reuters Datastream; Federal Reserve Bank of St. Louis; Eurostat Datastream.

Table 2.3: Descriptive Statistics of After-crisis Sample

After Crisis	VSTOXX	VIX	ECB RATES	M3 GROWTH RATE		
Mean	21.6624	18.4589	0.3540	1.0563		
Median	20.4950	16.8991	0.0250	0.9851		
Maximum	35.3500	34.4937	1.5000	4.5961		
Minimum	11.9900	10.3079	0.0000	-1.2145		
Standard Dev.	6.0060	5.7422	0.5068	0.8561		
Skewness	0.4333	1.0182	1.1535	0.9792		
Kurtosis	-0.4680	0.4266	-0.0591	5.4453		
Observations	50	50	50	50		
	GREECE BOND SPREADS	GDP GROWTH RATE - GREECE	BUDGET DEFICIT - GREECE	S&P - GREECE	MOODY'S - GREECE	FITCH - GREECE
Mean	7.0895	-0.2904	-5.6980	3.1800	1.4000	3.3200
Median	5.9108	-0.0286	-5.0000	2.0000	1.0000	3.0000
Maximum	23.9795	6.5222	6.2000	10.0000	12.0000	10.0000
Minimum	1.1476	-11.8382	-30.7000	-4.0000	-4.0000	0.0000
Standard Dev.	5.5556	2.8134	6.9395	2.5848	3.6309	2.8745
Skewness	1.5136	-1.1954	-0.8709	-0.1257	0.3800	0.2503
Kurtosis	2.2990	5.0901	2.1730	0.8332	-0.0496	-1.1147
Observations	50	50	50	50	50	50
	IRELAND BOND SPREADS	GDP GROWTH RATE - IRELAND	BUDGET DEFICIT - IRELAND	S&P - IRELAND	MOODY'S - IRELAND	FITCH - IRELAND
Mean	1.7798	1.8764	-5.9080	12.4200	10.5800	11.8800
Median	0.7124	1.0553	-2.6000	13.0000	11.0000	12.0000
Maximum	7.9145	23.2943	4.5000	15.0000	16.0000	15.0000
Minimum	0.2675	-4.4396	-41.8000	10.0000	7.0000	10.0000
Standard Dev.	2.0667	4.4251	9.6813	1.6047	2.3395	1.5471
Skewness	1.7060	2.6351	-2.4561	-0.4820	-0.0355	0.1740
Kurtosis	1.8179	10.7873	6.3339	-1.1428	-0.1497	-1.0087
Observations	50	50	50	50	50	50
	ITALY BOND SPREADS	GDP GROWTH RATE - ITALY	BUDGET DEFICIT - ITALY	S&P - ITALY	MOODY'S - ITALY	FITCH - ITALY
Mean	2.0123	0.1114	-3.9340	9.4800	9.6800	10.1600
Median	1.6692	0.1511	-2.7000	9.0000	9.0000	10.0000
Maximum	4.6789	13.3854	2.1000	13.0000	15.0000	14.0000
Minimum	0.8469	-11.3752	-12.6000	8.0000	8.0000	8.0000
Standard Dev.	0.9187	2.7469	4.2347	1.5680	2.3074	1.8223
Skewness	1.3786	0.7479	-0.4986	1.3949	1.7168	1.1863
Kurtosis	1.3047	16.7195	-0.9080	0.8559	1.5004	0.4612
Observations	50	50	50	50	50	50
	PORTUGAL BOND SPREADS	GDP GROWTH RATE - PORTUGAL	BUDGET DEFICIT - PORTUGAL	S&P - PORTUGAL	MOODY'S - PORTUGAL	FITCH - PORTUGAL
Mean	3.1146	0.2836	-4.4740	7.8400	7.6600	8.4200
Median	2.3217	0.3419	-3.7000	8.0000	7.0000	8.0000
Maximum	11.3889	13.4163	5.5000	13.0000	15.0000	14.0000
Minimum	0.6046	-15.0586	-19.0000	6.0000	5.0000	7.0000
Standard Dev.	2.7303	3.1127	4.6384	1.6208	2.3440	1.8962
Skewness	1.6057	-0.8907	-0.4731	0.8088	1.5972	1.7752
Kurtosis	1.9722	17.8455	1.1275	0.8114	2.9781	3.0391
Observations	50	50	50	50	50	50
	SPAIN BOND SPREADS	GDP GROWTH RATE - SPAIN	BUDGET DEFICIT - SPAIN	S&P - SPAIN	MOODY'S - SPAIN	FITCH - SPAIN
Mean	1.6850	0.2489	-6.5300	11.0800	10.2800	11.1800
Median	1.2513	0.3006	-5.8000	11.0000	10.0000	11.0000
Maximum	5.0741	15.4166	2.7000	16.0000	17.0000	17.0000
Minimum	0.6691	-17.4635	-24.8000	8.0000	8.0000	9.0000
Standard Dev.	1.1058	3.5057	5.6488	2.1744	2.4581	2.2195
Skewness	1.5778	-1.0319	-0.9511	0.5632	1.7149	1.5251
Kurtosis	1.7412	19.9607	1.7103	-0.3532	1.8606	1.2363
Observations	50	50	50	50	50	50

Note: This table presents the descriptive statistics after the European debt crisis, i.e., from Q1 2010 to Q2 2022. The descriptive statistics are rounded to four decimal places.
Source: Thomson Reuters Datastream; Federal Reserve Bank of St. Louis; Eurostat Datastream.

2.5 Empirical Findings

After estimating equation 2.1 using dynamic panel data methods introduced by De Santis (2014), the benchmark outputs are presented in Table A2 (in Appendix A). The results obtained using the EViews 8 econometric package show that the bond spreads of all countries significantly correlate with their lagged values, with the significance among coefficients being structurally different. Notably, the spreads of Greece and Spain are significantly affected by interest rates but in opposite signs, which is also observed in the coefficients of credit rating. The impacts of VSTOXX are only significant in the Greece model. Furthermore, only Ireland and Portugal are sensitive to high global risk perception. More regressions are discussed in the following part to uncover the reasons behind these results.

Tables 2.4 to 2.8 present the empirical outputs of each country. Panel A shows the whole sample model of the dataset from 2000 to 2022, which includes nine regressions. Regression VI and VII are sensitivity analyses excluding the lagged value of bond spreads, while regressions VIII and IX are robustness tests by changing credit agencies. Panel B includes the models of the first sub-period, and Panel C of the second sub-period, with 40 and 50 observations, respectively. The first column of Panel A is presented in Table A2 as the benchmark models of five countries. Columns II and III are obtained by substituting VSTOXX into VIX and substituting interest rates into M3. Adding macroeconomic fundamentals into the model yields column IV, while column V adds the dummy variable of the bailout, which is left blank in Panel B as it is before the European sovereign debt crisis. Regression V is not applicable to Italy and Spain, which did not receive a bailout from the Troika. The models in the first sub-period of Italy (regression VIII) and Portugal (regressions VIII and IX) are invalid, as their credit ratings were constant before the European debt crisis. The discussion will focus on regressions I to V.

The analysis of the benchmark model in Table 2.4 reveals that the Greek sovereign bond spreads and ECB interest rates exhibit a positive correlation, which was not significant prior to the European debt crisis. Furthermore, the relationship between M3 and Greek bond spreads, as another way to measure monetary policy, displays a significant negative correlation in the post-crisis model (Model III). The inclusion of the bailout variable in Model V demonstrates a significant negative correlation between the bailout and the bond spreads in Greece. These findings confirm the efficacy of monetary easing and economic relief measures in reducing government bond spreads in the Greek context. However, it is important to note that this relationship was not significant in the pre-crisis model, which highlights the impact of changing investor expectations on the market. From a macroeconomic perspective, there was a significant negative correlation[11] between the Greek bond spreads and GDP growth rate before the crisis, which aligns with the study's hypothesis. However, this significance disappeared after the crisis, indicating that investors in Greek government bonds no longer prioritized the impact of GDP on bond spreads. Furthermore, prior to the crisis, the VSTOXX and VIX indexes were significantly negatively correlated with the Greek bond spreads, with the VIX coefficient having a greater influence. However, after the crisis, the significance of the VIX effect disappeared, and the coefficient of VSTOXX showed a significant influence of 99%, which was stronger than before the crisis (0.14 after the crisis and 0.01 before the crisis). Finally, the study finds that Standard & Poor's credit ratings and Greek bond spreads exhibit a significant negative correlation in almost all models, as expected. However, the Moody's and Fitch ratings were not significant, indicating that Standard & Poor's ratings

[11] It is not surprising that the positive correlation with the interest rate turns into negative correlation with M3, since the monetary aggregate and interest rate are negatively related by the money demand function. For the same reason, they cannot be in the same equation, but can be used as alternative measures of monetary policy in different equations, as applied in this model.

are more closely linked to the Greek bond spreads than the ratings of the other two agencies.

The analysis of the Irish model shows that the relationship between monetary policy and government bond spreads was significant before and after the crisis, but with opposite effects. Contrary to our assumptions, adjustments of interest rates before the crisis were significantly associated with an increase in Irish bond spreads. This suggests that, prior to the European sovereign debt crisis, the ECB's monetary policy did not consider the creditworthiness of Ireland's national debt, and the policy implemented actually worsened Ireland's sovereign credit. Unlike the Greek model, M3 and the bailout variable from the the Troika were insignificant in the models over time, indicating that adjustments in M3 and external bailouts had little impact on Irish sovereign bond spreads. In terms of macroeconomic variables, the budget deficit variable had a significant negative correlation with Irish spreads over the overall timeline, consistent with our hypothesis, and indicating that Ireland's sovereign bond spreads are closely related to the government's financial situation. From the perspective of the market outlook, the VSTOXX and VIX indexes showed significant positive coefficients before the crisis, but only VSTOXX was significantly correlated with a negative sign after the crisis. The results before the crisis are in line with our assumptions, but not after the crisis, as increased panic in the European market will reduce Irish government bond spreads. The reason for this may be that panic in the European stock market arises from the performance of other Eurozone countries, and Ireland's relatively better performance leads to lower sovereign bond spreads. However, if the stock market panic originates from the core country Germany, then the rise in German sovereign bond yields will also cause a decrease in Irish bond spreads. The credit rating variable was insignificant in the model excluding robustness regressions, suggesting a weak correlation between credit rating and

Irish bond spreads.

The results of the Italian model suggest that, similar to Greece, the correlation between Italian bond spreads and the ECB interest rate is positive only after the crisis, which confirms our hypothesis. However, there is no significant relationship between M3 and Italian bond spreads. With regards to macroeconomic variables, the results from the three panels align with our hypothesis that there is a significant negative correlation between Italy's sovereign bond spreads and GDP growth rate - it confirms that Italy's sclerotic economic growth cannot be neglected from the perspective of market. After the crisis, there is a significant positive correlation between the government fiscal status and bond spreads, which is unexpected. This implies that a worsening of the Italian government's finances will improve the credit of government bonds. One possible explanation for this is that the market's pessimism towards Italy's high debt level is the primary reason for its high-risk sovereign credit level after the crisis. As Italy paid down its debt, it led to lower debt levels, which improved creditworthiness but worsened government finances. Overall, the Italian bond spreads are more closely related to the VIX index, as the significance of the VIX index persists in the model of all three periods, while the significance of the VSTOXX index emerges only in the pre-crisis model. Unlike in the Italian scenario, the Greek model exhibits greater significance for VSTOXX post-crisis compared to the pre-crisis phase, which may signify that the European stock market's crisis-induced panic sentiment is more strongly associated with Greece than Italy. In terms of credit rating, the significance of the credit rating coefficient was negative before the crisis, in line with our hypothesis, but its significance disappeared after the crisis, similar to the Irish model. This indicates that the correlation between Italy's sovereign credit rating and sovereign debt spreads weakened after the crisis compared to before it. Furthermore, in the whole sample model, the credit rating variable demonstrates an insignificant characteristic. This implies that for investors in government bonds, the impact of changes in credit ratings on Italian bond spreads can be disregarded in long-term considerations.

In the Portuguese model, the coefficient pertaining to the ECB interest rate exhibits significance solely during the post-crisis era. This finding corroborates the preceding hypothesis and aligns with results from the Italian model. In congruence with the Irish model, there is an absence of evidence indicating a substantial relationship between the M3 money supply, bailouts, and Portuguese bond spreads across all time periods. During the pre-crisis phase, the coefficient signifying the relationship between GDP growth and Portuguese sovereign bond spreads denotes a notably negative correlation, which is in accord with our investigative hypothesis. However, such a relationship is not evident in the post-crisis period, suggesting that the bond market's attention may not be concentrated on Portugal's economic fundamentals. And the fiscal position of the Portuguese government fails to provide an explanation for bond spreads across all models. Unlike in previous countries, the coefficients corresponding to VSTOXX and VIX indexes attain significance solely in the pre-crisis model. Moreover, VIX (0.012) displays a stronger connection to Portuguese bond spreads compared to VSTOXX (0.006). This suggests that, prior to the crisis, Portuguese bond spreads are more intimately associated with US stock markets than with European stock markets. However, following the crisis, the association between the debt crisis and the stock market diminishes in significance. In the examination of Portugal, several country-specific variables lose their significance post-crisis compared to pre-crisis. We infer that Portugal's sovereign bond market may be more affected by external spillovers after crisis, and this hypothesis will be discussed in Chapter 4 of the thesis. Synthesizing results from the nine models, credit ratings hold significance only within the pre-crisis model. Notably, in the post-crisis phase, both the fiscal position and credit rating variables are significant in the robustness test conducted with the lagged term removed (VII regression). Nevertheless, given that the lag term displays 99% significance across all models, we assess the necessity of the lag term's presence and subsequently determine the insignificant results of budget deficit and credit rating (Standard & Poor, and Moody's). In contrast, Fitch, diverging from the other two rating agencies, manifests significance in the post-crisis model, which may offer valuable insights to investors in Portugal's sovereign bond market.

The findings gleaned from the Spanish model reveal that, akin to the Italian and Portuguese models, the coefficient for the ECB interest rate attains significance exclusively in the post-crisis period. The signs of these coefficients, both positive and negative, align with our initial hypotheses. However, M3 remains insignificant throughout all models. This implies that the ECB's interest rate reductions failed to exert a significant impact on the bond markets of Italy, Spain, and Portugal before the crisis . In the pre-crisis model, the GDP growth rate coefficient and the Spanish sovereign bond spreads exhibit a significant negative correlation, but not in the post-crisis model, which mirrors the patterns detected in the Portuguese model. Of particular note are the coefficients of VSTOXX and VIX, which maintain significance in both pre-crisis and post-crisis models, and their signs are congruent with our hypotheses. The values of the coefficients suggest that the relationship between the VIX index and Spanish bond spreads is stronger than that with the VSTOXX index. This indicates that the Spanish sovereign bond market shares a close correlation with both European and American stock markets in the pre- and post-crisis models, exhibiting an even closer correlation with the American stock market. Regarding credit rating, the ratings from Moody's and Fitch (significant and negative) are likely to be more closely associated with Spanish sovereign bond spreads than Standard & Poor's in the post-crisis model. In the pre-crisis model, the credit ratings from Standard & Poor's and Fitch have a significantly positive relationship with Spanish sovereign bond spreads, a result contrary to our hypothesis. This outcome could potentially be attributed to the substantial disparity in the frequency of changes between credit rating and sovereign bond spreads. For instance, in the pre-crisis model, Standard & Poor's announced adjustments to Spain's sovereign credit rating five times, three of which were concentrated in 2009 - during the GFC' impact on the Spanish sovereign market. Fitch, on the other hand, adjusted Spain's sovereign rating only once, in the third quarter of 2000. Meanwhile, in the post-crisis model, Moody's adjusted Spain's sovereign credit rating 13 times and Fitch 10 times, with Standard & Poor's making 14 adjustments to Spain's sovereign rating. Consequently, we posit that the significance of the negative correlation in the post-crisis period holds greater instructive value than that of the pre-crisis period.

Table 2.4: Dynamic Panel Regressions Outputs of Greece

PANEL A - WHOLE SAMPLE BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	1.9375***	1.9856***	0.740269	2.1347***	2.1241***	8.7987***	8.7014***	-0.0791	0.0254
BOND SPREADS (-1)	0.7608***	0.7775***	0.8527***	0.7378***	0.7356***			0.9078***	0.9271***
ECB RATES	0.6604***	0.6641***		0.6610***	0.6561***	1.6910***	1.6075***	0.1551	0.1247
M3			-0.0364						
VSTOXX	0.0369*		0.0405*	0.0295	0.0300	0.1171***	0.0889**	0.0247	0.0218
VIX		0.0310							
GDP GROWTH RATE				-0.0967	-0.0958		-0.1631		
BUDGET DEFICIT				-0.0293	-0.0285		-0.1103**		
BAILOUT					0.0558				
HIGH GLOBAL RISK PERCEPTION	0.5246	0.5822	0.2232	0.4263	0.4155	-0.4549	-0.6423	0.5291	0.5348
STANDARD & POOR	-0.4650***	-0.4509***	-0.1571***	-0.4747***	-0.4723***	-1.4774***	-1.4359***		
MOODY'S								-0.0971	
FITCH									-0.0962
OBSERVATIONS	90	90	90	90	90	90	90	90	90
R-SQUARED	0.9434	0.9423	0.9309	0.9465	0.9465	0.7856	0.8071	0.9251	0.9246

PANEL B BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	2.7846**	3.2607***	2.6125**	2.2895*		3.9335***	3.6617***	-0.1307	1.1591
BOND SPREADS (-1)	0.4142**	0.3039**	0.6367***	0.4781**				0.4279**	0.4397**
ECB RATES	-0.1736	-0.1948**		-0.0949		-0.3617***	-0.3213***	-0.2276**	-0.2286**
M3			-0.0394						
VSTOXX	0.0149***		0.0176***	0.0115**		0.0133**	0.0101*	0.0104*	0.0123**
VIX		0.0287***							
GDP GROWTH RATE				-0.0485*			-0.0424		
BUDGET DEFICIT				-0.0109			-0.0086		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	-0.1045	-0.2408**	-0.2170	-0.0477		0.0298	0.0945	0.0928	-0.0070
STANDARD & POOR	-0.1770*	-0.2110***	-0.2252**	-0.1634		-0.1941*	-0.1836*		
MOODY'S								0.0812	
FITCH									-0.0221
OBSERVATIONS	40	40	40	40		40	40	40	40
R-SQUARED	0.8272	0.8994	0.8187	0.8541		0.8049	0.8249	0.8130	0.8119

PANEL C BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	0.7276	1.8750	1.0832	0.4976	0.959	2.9195**	2.6898*	-1.0183	-0.1321
BOND SPREADS (-1)	0.5777***	0.6442***	0.7247***	0.5799***	0.5948***			0.6301***	0.5908***
ECB RATES	2.9277***	2.7443***		3.1762***	4.7777***	6.3914***	6.6638***	3.3410***	3.6694***
M3			-0.5964*						
VSTOXX	0.1351***		0.1372**	0.1517***	0.1321***	0.2699***	0.2865***	0.1465***	0.1347**
VIX		0.0606							
GDP GROWTH RATE				-0.0240	-0.0261		-0.0056		
BUDGET DEFICIT				0.0543	0.0375		0.0504		
BAILOUT					-2.0945***				
HIGH GLOBAL RISK PERCEPTION	-0.9460	-0.2317	0.8512	-0.8813	-1.1028	-4.3106***	-4.2642***	-1.6669*	-1.4179
STANDARD & POOR	-0.4245***	-0.4248***	-0.5567***	-0.4095***	-0.4010***	-0.7507***	-0.7377***		
MOODY'S								-0.0769	
FITCH									-0.2008
OBSERVATIONS	50	50	50	50	50	50	50	50	50
R-SQUARED	0.9415	0.9319	0.9222	0.9446	0.9536	0.8557	0.8583	0.9255	0.9280

Note: This table presents the dynamic panel regressions for Greece. Among three panels, Panel A includes the whole sample data; Panel B includes outputs before the European debt crisis; Panel C includes after-crisis models. There are nine regressions in each panel. The sensitivity analysis regressions are VI to IX. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

Table 2.5: Dynamic Panel Regressions Outputs of Ireland

PANEL A - WHOLE SAMPLE BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	-0.4046	-0.3999	-0.1124	0.8487	0.2326	11.8633***	11.3814***	-0.3830	0.3390
BOND SPREADS (-1)	0.9820***	0.9708***	0.9619***	0.8530***	0.8362***			0.9930***	0.9374***
ECB RATES	-0.0240	-0.0215		0.0737	0.0302	0.6127***	0.6913***	-0.0396	0.0263
M3			-0.0245						
VSTOXX	-0.0051		-0.0048	-0.0078	-0.0067	0.0152	-0.0046	-0.0048	-0.0043
VIX		0.0034							
GDP GROWTH RATE				-0.0048	-0.0028		-0.0312		
BUDGET DEFICIT				-0.0234***	-0.0229***		-0.0520***		
BAILOUT					0.3016				
HIGH GLOBAL RISK PERCEPTION	0.3153**	0.2390*	0.3288***	0.3671**	0.3336**	1.1180***	1.2088***	0.2815**	0.3700***
STANDARD & POOR	0.0326	0.0219	0.0120	-0.0591	-0.0130	-0.8889***	-0.8391***		
MOODY'S								0.0350	
FITCH									-0.0258
OBSERVATIONS	90	90	90	82	82	90	82	90	90
R-SQUARED	0.9398	0.9395	0.9398	0.9485	0.9491	0.7240	0.8340	0.9403	0.9398

PANEL B BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	-0.7998	0.7076	0.8852	-48.8188***		0.7754	-25.5119***	-8.4380**	-8.2921***
BOND SPREADS (-1)	0.4549**	0.3614**	0.8357***	1.1109***				0.4262**	0.6379***
ECB RATES	-0.3554**	-0.3403***		-1.9617***		-0.5877***	-1.6126***	-0.4174***	-0.4015***
M3			-0.0181						
VSTOXX	0.0096*		0.0138**	-0.0019		0.0102*	0.0039	0.0096**	0.0092**
VIX		0.0240***							
GDP GROWTH RATE				0.0197*			0.0232		
BUDGET DEFICIT				-0.0094			-0.0304***		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	0.0333	-0.1471	-0.1094	-0.0509		0.0765	0.0515	-0.0227	-0.0614
STANDARD & POOR	0.1271	0.0232	-0.0645	3.3639***		0.0930	1.9024***		
MOODY'S								0.5920**	
FITCH									0.5794***
OBSERVATIONS	40	40	40	32		40	32	40	40
R-SQUARED	0.8739	0.9223	0.8501	0.9813		0.8557	0.9636	0.8915	0.9048

PANEL C BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	0.9601	0.8106	0.5842	1.1206	1.0064	6.4885***	6.1983***	0.6411	1.9086**
BOND SPREADS (-1)	0.7526***	0.7502***	0.9503***	0.8146***	0.8110***			0.7661***	0.6888***
ECB RATES	0.8975**	0.8296**		0.4114	0.4096	2.6882***	2.8516***	0.9043**	1.0110***
M3			-0.0721						
VSTOXX	-0.0318**		-0.0280*	-0.0316**	-0.0314**	-0.0154	-0.0156	-0.0326**	-0.0323**
VIX		-0.0283							
GDP GROWTH RATE				-0.0047	-0.0043		-0.0184		
BUDGET DEFICIT				-0.0186	-0.0184		0.0120		
BAILOUT					0.0516				
HIGH GLOBAL RISK PERCEPTION	0.6628***	0.7171***	0.7198***	0.5915**	0.5829**	1.0755***	1.1097***	0.6336***	0.7633***
STANDARD & POOR	-0.0323	-0.0330	-0.0073	-0.0467	-0.0383	-0.4601***	-0.4335***		
MOODY'S								-0.0076	
FITCH									-0.1099
OBSERVATIONS	50	50	50	50	50	50	50	50	50
R-SQUARED	0.9520	0.9493	0.9451	0.9547	0.9548	0.8992	0.9021	0.9519	0.9544

Note: This table presents the dynamic panel regressions for Ireland. Among three panels, Panel A includes the whole sample data; Panel B includes outputs before the European debt crisis; Panel C includes after-crisis models. There are nine regressions in each panel. The sensitivity analysis regressions are VI to IX. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

Table 2.6: Dynamic Panel Regressions Outputs of Italy

PANEL A – WHOLE SAMPLE BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	0.0875	−0.1545	0.1283	0.1997		1.2424	1.3670	−0.3365	−0.4230
BOND SPREADS (-1)	0.9374***	0.9274***	0.9340***	0.9282***				0.9440***	0.9387***
ECB RATES	−0.0038	−0.0310		−0.0076		−0.4578***	−0.4582***	−0.0659	−0.0688
M3			−0.0094						
VSTOXX	0.0049		0.0050	0.0028		0.0226*	0.0189	0.0048	0.0043
VIX		0.0147**							
GDP GROWTH RATE				−0.0364**			−0.0644		
BUDGET DEFICIT				0.0127			0.0139		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	0.1178	−0.0187	0.1182	0.1636		−0.5151*	−0.4473*	0.0545	0.0796
STANDARD & POOR	−0.0125	0.0034	−0.0154	−0.0135		0.0528	0.0524		
MOODY'S								0.0348	
FITCH									0.0431
OBSERVATIONS	90	90	90	90		90	90	90	90
R-SQUARED	0.9066	0.9109	0.9066	0.9139		0.4817	0.5004	0.9086	0.9087

PANEL B BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	0.7509	0.6766*	1.0365**	0.8630*		2.9243***	2.5086***		0.8547
BOND SPREADS (-1)	0.8546***	0.6792***	0.7095***	0.7289***					0.9768***
ECB RATES	0.0532	0.0043		0.0187		−0.1144***	−0.1337***		0.0516
M3			0.0030						
VSTOXX	0.0063***		0.0063***	0.0048**		0.0073**	0.0041		0.0074***
VIX		0.0127***							
GDP GROWTH RATE				−0.0451*			−0.0902***		
BUDGET DEFICIT				−0.0017			−0.0040		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	0.0320	−0.0396	0.0343	0.0397		0.1728**	0.1465**		−0.0904*
STANDARD & POOR	−0.0754**	−0.0581**	−0.0778**	−0.0682**		−0.1671***	−0.1259***		
MOODY'S									
FITCH									−0.0816*
OBSERVATIONS	40	40	40	40		40	40	40	40
R-SQUARED	0.8942	0.9331	0.8879	0.9056		0.7822	0.8385		0.8846

PANEL C BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	0.9452	0.1385	−0.8600	1.2557		4.2763***	4.5466***	0.8374	0.4384
BOND SPREADS (-1)	0.7714***	0.7311***	0.8538***	0.7873***				0.6957***	0.7575***
ECB RATES	0.5646*	0.4998**		0.5587**		1.8351***	1.8451***	0.6566	0.4645
M3			0.0265						
VSTOXX	0.0065		0.0182	0.0069		0.0057	0.0052	0.0090	0.0117
VIX		0.0419**							
GDP GROWTH RATE				−0.0348*			−0.0346		
BUDGET DEFICIT				0.0345**			0.0227		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	0.1413	−0.2877	−0.0604	0.3444		−0.3460	−0.2081	0.0067	−0.0122
STANDARD & POOR	−0.0907	−0.0452	0.0816	−0.1204		−0.3073**	−0.3305**		
MOODY'S								−0.0662	
FITCH									−0.0342
OBSERVATIONS	50	50	50	50		50	50	50	50
R-SQUARED	0.8245	0.8485	0.8096	0.8537		0.5126	0.5310	0.8240	0.8216

Note: This table presents the dynamic panel regressions for Italy. Among three panels, Panel A includes the whole sample data; Panel B includes outputs before the European debt crisis; Panel C includes after-crisis models. There are nine regressions in each panel. The sensitivity analysis regressions are VI to IX. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

Table 2.7: Dynamic Panel Regressions Outputs of Portugal

PANEL A - WHOLE SAMPLE BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	0.6662	0.5440	-0.0046	0.7341	0.6850	11.1388***	10.7147***	-0.3643	0.3310
BOND SPREADS (-1)	0.9448***	0.9401***	0.9768***	0.9329***	0.9097***			1.0077***	0.9663***
ECB RATES	0.1330	0.1288		0.1333	0.1126	1.4669***	1.3964***	-0.0373	0.0745
M3			-0.0158						
VSTOXX	-0.0043		-0.0034	-0.0069	-0.0063	0.0258	0.0153	-0.0052	-0.0043
VIX		0.0051							
GDP GROWTH RATE				-0.0229	-0.0223		-0.0359		
BUDGET DEFICIT				-0.0154	-0.0157		-0.0928**		
BAILOUT					0.2100				
HIGH GLOBAL RISK PERCEPTION	0.5939***	0.4950**	0.4638***	0.5874***	0.5633***	1.4810***	1.3529***	0.4295**	0.5380***
STANDARD & POOR	-0.0885	-0.0908	-0.0030	-0.0932	-0.0841	-1.2367***	-1.1963***		
MOODY'S								0.0345	
FITCH									-0.0460
OBSERVATIONS	90	90	90	90	90	90	90	90	90
R-SQUARED	0.9436	0.9436	0.9426	0.9447	0.9449	0.6571	0.6805	0.9429	0.9431

PANEL B BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	1.8527	1.5649**	1.8577**	1.5947**		3.4631***	3.2148***		
BOND SPREADS (-1)	0.6564***	0.5133***	0.5409***	0.6644***					
ECB RATES	0.0478	0.0038		0.0311		-0.0594	-0.0725		
M3			-0.0044						
VSTOXX	0.0056**		0.0056**	0.0035		0.0056*	0.0034		
VIX		0.0123***							
GDP GROWTH RATE				-0.0488*			-0.0475		
BUDGET DEFICIT				0.0012			-0.0012		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	0.0705	0.0042	0.0687	0.0670		0.2151***	0.2163***		
STANDARD & POOR	-0.1460***	-0.1177***	-0.1304**	-0.1187**		-0.2197***	-0.1948***		
MOODY'S									
FITCH									
OBSERVATIONS	40	40	40	40		40	40		
R-SQUARED	0.8333	0.8840	0.8284	0.8504		0.7641	0.7800		

PANEL C BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	1.1139	0.8945	-0.2086	1.3050	1.5597	5.5465***	5.5974***	0.8556	2.4243***
BOND SPREADS (-1)	0.7006***	0.6917***	0.9635***	0.6794***	0.7010***			0.6593***	0.5733***
ECB RATES	1.5759***	1.6216***		1.7605***	1.8687***	4.3854***	4.6463***	1.7978***	2.2709***
M3			-0.1466						
VSTOXX	0.0103		0.0095	0.0138	0.0111	0.0494	0.0584*	0.0151	0.0103
VIX		0.0326							
GDP GROWTH RATE				-0.0189	-0.0207		-0.0201		
BUDGET DEFICIT				0.0292	0.0326		0.0715*		
BAILOUT					-0.3073				
HIGH GLOBAL RISK PERCEPTION	0.2813	0.0557	0.7668*	0.2945	0.3607	-0.5633	-0.4982	0.1379	0.2334
STANDARD & POOR	-0.1349	-0.1434	0.0004	-0.1520	-0.1821	-0.6187***	-0.6233***		
MOODY'S								-0.1045	
FITCH									-0.2613***
OBSERVATIONS	50.0000	50.0000	50.0000	50.0000		50.0000	50.0000	50.0000	50.0000
R-SQUARED	0.9462	0.9478	0.9293	0.9480	0.9485	0.8682	0.8782	0.9463	0.9549

Note: This table presents the dynamic panel regressions for Portugal. Among three panels, Panel A includes the whole sample data; Panel B includes outputs before the European debt crisis; Panel C includes after-crisis models. There are nine regressions in each panel. The sensitivity analysis regressions are VI to IX. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

Table 2.8: Dynamic Panel Regressions Outputs of Spain

PANEL A - WHOLE SAMPLE BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	-0.8986***	-0.9015***	-0.3973*	-0.8430***		3.9039***	3.6718***	-0.3769*	-0.5313**
BOND SPREADS (-1)	1.0230***	1.0251***	1.0120***	1.0242***				0.9904***	0.9931***
ECB RATES	-0.0791**	-0.0740**		-0.0794**		0.0198	0.1290	-0.0394	-0.0473
M3			-0.0030						
VSTOXX	0.0060		0.0039	0.0052		0.0189	0.0062	0.0045	0.0054
VIX		0.0098*							
GDP GROWTH RATE				-0.0220*			0.0004		
BUDGET DEFICIT				0.0035			-0.0692***		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	-0.0348	-0.0720	0.0697	-0.0191		0.1176	0.0164	0.0510	0.0285
STANDARD & POOR	0.0677***	0.0640***	0.0207	0.0660***		-0.2531***	-0.2476***		
MOODY'S								0.0263	
FITCH									0.0368*
OBSERVATIONS	90	90	90	90		90	90	90	90
R-SQUARED	0.9473	0.9483	0.9434	0.9496		0.4228	0.5102	0.9433	0.9440

PANEL B BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	-1.2591*	-0.7318	-1.4246*	-0.0703		-0.8430	0.3847	0.4734	-2.5013***
BOND SPREADS (-1)	0.7922***	0.5923***	0.8255***	0.4774***				0.8198***	0.7153***
ECB RATES	-0.0142	-0.0411		-0.0174		-0.1463***	-0.0751***	-0.0130	0.0162
M3			-0.0112						
VSTOXX	0.0041**		0.0043**	-0.0005		0.0046*	-0.0016	0.0052**	0.0039**
VIX		0.0096***							
GDP GROWTH RATE				-0.1186***			-0.1429***		
BUDGET DEFICIT				-0.0039			-0.0082*		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	0.0415	0.0008	0.0365	0.0987**		0.1861***	0.1845	-0.0472	0.1277*
STANDARD & POOR	0.0754*	0.0470	0.0828*	0.0175		0.0865*	0.0092		
MOODY'S								-0.0293	
FITCH									0.1409***
OBSERVATIONS	40	40	40	40		40	40	40	40
R-SQUARED	0.8394	0.8884	0.8404	0.9148		0.7454	0.8885	0.8283	0.8560

PANEL C BOND SPREADS	I	II	III	IV	V	VI	VII	VIII	IX
C	-0.3963	-0.3158	-1.6429***	-0.3050		3.5626***	3.5768***	0.8000	0.8723
BOND SPREADS (-1)	0.7704***	0.7702***	0.9656***	0.7764***				0.6184***	0.6343***
ECB RATES	0.4976**	0.5542***		0.5013**		2.0353***	2.0229***	0.9385***	0.8946***
M3			0.0191						
VSTOXX	0.0209**		0.0243**	0.0205**		0.0214	0.0196	0.0161*	0.0155*
VIX		0.0291***							
GDP GROWTH RATE				-0.0171			-0.0100		
BUDGET DEFICIT				0.0060			-0.0025		
BAILOUT									
HIGH GLOBAL RISK PERCEPTION	-0.2137	-0.2955*	-0.3123*	-0.1713		-0.0894	-0.0891	-0.0513	-0.0470
STANDARD & POOR	0.0214	0.0076	0.1152***	0.0156		-0.2734***	-0.2720***		
MOODY'S								-0.0792**	
FITCH									-0.0792*
OBSERVATIONS	50	50	50	50		50	50	50	50
R-SQUARED	0.9418	0.9438	0.9326	0.9440		0.8230	0.8244	0.9468	0.9458

Note: This table presents the dynamic panel regressions for Spain. Among three panels, Panel A includes the whole sample data; Panel B includes outputs before the European debt crisis; Panel C includes after-crisis models. There are nine regressions in each panel. The sensitivity analysis regressions are VI to IX. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

All the models - including the lagged term of bond spreads, show that the lagged term is significant, similar to previous studies (De Santis, 2014; Tebaldi et al.'s, 2018), confirming the importance of inertia in the dynamics of the bond spreads. The significance of the dummy variable 'high global risk perception' is also noteworthy, as it is only significant in the Irish and Portuguese cases. This suggests that Irish and Portuguese bond spreads are more vulnerable to global investment sentiment than the other three countries. There are, however, subtle differences between these two countries. In the Irish model, the significance of high global risk perception mainly exists in the whole sample model and the post-crisis model, while in the Portuguese model, its significance mainly exists in the whole sample model. This indicates that even though the bond spreads of these two countries are more sensitive to the panic in the US stock market in the long run, there is a clear difference in the response of the Irish government bond before and after the crisis. This discrepancy may be attributable to Ireland's robust post-crisis recovery when compared to other peripheral countries. In relation to public debt, Ireland's figures have exhibited an annual decrease since 2014, while the debt metrics of the other four nations have persistently demonstrated a slow upward trend. Considering GDP, in contrast with Ireland, Portugal, and Spain, who experienced gradual GDP recovery post-crisis, Italy and Greece endured sustained negative growth for an extended period. Intuitively, the volatility of sovereign bond spreads in all countries, bar Ireland, does not bear a close connection to global investment risk because they remain ensnared in economic fundamental predicaments. On the other hand, prior to the GFC, Ireland experienced the specific period 'Celtic Tiger'/footnote'Celtic Tiger' is described as a rapid economic growth in Ireland since 1995 to 2007.. When juxtaposed with the impact of the rapidly expanding real economy on sovereign bond spreads, the relationship between global investment risk and Irish sovereign credit appears insignificant.

Through comparing the results of the five-country model, several important conclusions can be drawn. Firstly, the ECB's overnight deposit rate has a stronger relationship with sovereign bond spreads than M3. However, it should be noted that there are some exceptions to this correlation, as the negative signs observed on Ireland's bond spreads in the pre-crisis period are contrary to the hypothesis and suggest a lack of universality in the relationship between bond spreads and ECB rates over the 22-year period. Following the debt crisis, however, each announcement of increasing interest rates has widened the gap between these countries and German bond yields, confirming the generality of the hypothesis that monetary policy effectively controls the level of government bond spreads in these five countries in the post-crisis models. Additionally, the negative relationship between M3 and Greek spreads after the debt crisis provides further support for the effectiveness of monetary policies in reducing Greece's bond spreads, despite the Troika bailouts being ineffective in reducing Ireland and Portugal's spreads.

Moreover, the significance of the GDP growth rate variable only exists in the pre-crisis model for all countries except Italy, indicating that the market's focus has shifted to other factors. For Italy, the significance of government budgets only exists in the post-crisis model, suggesting that Italy, being the largest economy among the PIIGS, is more vulnerable to its own economic and fiscal situation after the crisis. Furthermore, Italy's higher average GDP supports the hypothesis that countries with better economic fundamentals are more susceptible to changes in investor sentiment.

The European fear index is generally positively correlated with sovereign bond spreads, except for Ireland. The positive correlations between Greek, Italian, Spanish and Portuguese bond spreads and VSTOXX indicate that investors tend to recognize the risks concentrated in these four countries, while there is negative correlation in Ireland, which could be mainly affected by spillover effects.

It could be explained by the fact that in Ireland, investors moved assets from the stock market to the bond market during the European stock market panic. Different from Ferrucci (2003) and Barrios et al. (2009), the VSTOXX index was found to be a better predictor of sovereign bond spreads than the VIX index after the debt crisis, while the reverse was true before the crisis. Our finding thus underscores the higher relevance of the European uncertainty measure, for the European countries in our sample, especially post-crisis. The dummy variable for high-risk perception was significant for Ireland and Portugal, highlighting potential differences in decisions on Irish and Portuguese sovereign bonds under different external pressure. Overall, these findings have important implications for understanding the relationship between stock market indexes and sovereign bond spreads in the European context and their implications for both investors and policymakers.

To assess the robustness of our models, we conducted a sensitivity analysis by excluding the lagged value of bond spreads in the benchmark model and macro-fundamental regression. Although the significance of some variables may have changed, the coefficient sign remained constant compared to the regressions with lagged spreads. This highlights the importance of including the lagged variable, as the addition of this variable resulted in a higher R-square of the model. We also substituted Standard & Poor's sovereign ratings into Moody's and Fitch and found that there were few differences in the coefficients and significance levels of other variables, and the credit rating coefficients are quite similar. In Appendix A, we drop two variables - credit rating and high global risk perception, as they represent high correlation with interest rates and VIX index. The robustness tests' results shown are not clearly distinguishable from either the significance or the signs of the coefficients. In conclusion, our sensitivity analysis provides evidence of the robustness of our regression models. /footnoteThere is possibility of the estimates that being affected by endogeneity bias. In Chapter 3, we employed vector autoregressive approach, addresses the research question as well, since it assume an interrelated vector of endogenous variables.

2.6 Conclusion

In this chapter, we employed dynamic panel regression to examine the determinants of the sovereign bond spreads of the PIIGS countries of the Euro area. Compared to the past literature, we used an extended sample period and adding macroeconomic and government administrative variables to the model. Our analysis contributed to the literature by providing a multidimensional analysis of sovereign bond spreads' determinants before and after the European debt crisis. We found significant differences in the determinants of bond spreads before and after the crisis, with macroeconomic variables having a greater impact before the crisis, while monetary policy had a more significant impact after the crisis.

Our empirical findings have important implications for monetary authorities and market participants. Following the sovereign debt crisis, the European Central Bank had aimed to reduce the sovereign credit risk of peripheral countries. However, the effectiveness of monetary policy might vary over time and across countries, and the differences between credit agencies suggested that investors should consider the credit agency most relevant to the country's sovereign bond when deciding on their European bond portfolios. We also found that the impact of the bailout plan on Greece's government bond spreads was more significant than in Ireland and Portugal.

One limitation of our study was the inclusion of high-frequency financial data and low-frequency macro data in the model. The inconsistency in the announcement date of the macro data prevented its correspondence with the daily financial data, resulting in a loss of high-frequency data information. This limitation is addressed in the subsequent two chapters.

Our study demonstrated that the determinants of sovereign bond spreads in the most affected countries by a crisis change significantly before and after the crisis.

Further analysis could be applied to other crises, such as the global pandemic, and exogenous variables should be carefully examined and considered in such analyses. Such research would aid in the analysis of investor decision-making and policy formulation in the face of systemic risk.

2.7 Appendix A

Table A1: Descriptive Statistics of Whole Sample

Whole Sample	VSTOXX	VIX	ECB RATES	M3 GROWTH RATE		
Mean	23.5763	20.0846	1.9272	1.3766		
Median	22.0150	18.2457	1.0000	1.3260		
Maximum	60.6800	58.5878	4.2500	4.5961		
Minimum	11.9900	10.3079	0.0000	-1.2145		
Standard Dev.	8.7479	7.7878	1.9066	1.0153		
Skewness	1.5927	1.9116	0.2915	0.3375		
Kurtosis	3.5515	6.2570	-1.7953	0.9189		
Observations	90	90	90	90		
	GREECE BOND SPREADS	GDP GROWTH RATE - GREECE	BUDGET DEFICIT - GREECE	S&P - GREECE	MOODY'S - GREECE	FITCH - GREECE
Mean	4.1917	0.1096	-6.5667	7.0667	6.4222	7.1222
Median	1.8394	0.0246	-6.1000	6.5000	5.0000	6.5000
Maximum	23.9795	6.5222	6.2000	13.0000	13.0000	13.0000
Minimum	0.1520	-11.8382	-30.7000	-4.0000	-4.0000	0.0000
Standard Dev.	5.2673	2.4218	6.0467	4.7918	6.2638	4.7989
Skewness	1.9308	-1.2731	-0.5757	-0.2119	-0.2413	-0.2648
Kurtosis	4.0119	6.0262	1.8459	-1.3930	-1.5415	-1.5150
Observations	90	90	90	90	90	90
	IRELAND BOND SPREADS	GDP GROWTH RATE - IRELAND	BUDGET DEFICIT - IRELAND	S&P - IRELAND	MOODY'S - IRELAND	FITCH - IRELAND
Mean	1.1399	1.3979	-4.3476	14.3111	13.4111	14.1111
Median	0.4663	0.9322	-2.0500	14.0000	12.0000	13.5000
Maximum	7.9145	23.2943	8.8000	17.0000	17.0000	17.0000
Minimum	-0.0383	-4.4396	-41.8000	10.0000	7.0000	10.0000
Standard Dev.	1.7400	3.6187	8.6443	2.4707	3.6285	2.7700
Skewness	2.3759	2.8613	-2.4394	-0.4036	-0.3951	-0.2183
Kurtosis	5.2134	14.9093	7.5545	-1.0811	-1.2527	-1.5488
Observations	90	90	82	90	90	90
	ITALY BOND SPREADS	GDP GROWTH RATE - ITALY	BUDGET DEFICIT - ITALY	S&P - ITALY	MOODY'S - ITALY	FITCH - ITALY
Mean	1.2909	0.1064	-3.6900	11.5444	12.0444	12.0667
Median	1.2212	0.1905	-2.5500	13.0000	15.0000	14.0000
Maximum	4.6789	13.3854	3.8000	15.0000	15.0000	15.0000
Minimum	0.1407	-11.3752	-12.6000	8.0000	8.0000	8.0000
Standard Dev.	1.0782	2.1296	4.3167	2.6613	3.1620	2.5563
Skewness	1.1172	0.8363	-0.5608	-0.0104	-0.1769	-0.2245
Kurtosis	1.0272	25.6953	-0.8438	-1.6868	-1.9315	-1.6905
Observations	90	90	90	90	90	90
	PORTUGAL BOND SPREADS	GDP GROWTH RATE - PORTUGAL	BUDGET DEFICIT - PORTUGAL	S&P - PORTUGAL	MOODY'S - PORTUGAL	FITCH - PORTUGAL
Mean	1.8678	0.2570	-4.6856	10.7667	10.9222	11.3444
Median	0.8209	0.3148	-4.1000	9.0000	10.5000	10.0000
Maximum	11.3889	13.4163	5.5000	15.0000	15.0000	15.0000
Minimum	0.0017	-15.0586	-19.0000	6.0000	5.0000	7.0000
Standard Dev.	2.4711	2.3875	4.0269	3.5317	4.0592	3.5763
Skewness	2.1595	-1.0429	-0.4633	-0.0200	-0.1187	-0.0686
Kurtosis	4.6037	28.5475	1.3475	-1.7079	-1.8039	-1.8788
Observations	90	90	90	90	90	90
	SPAIN BOND SPREADS	GDP GROWTH RATE - SPAIN	BUDGET DEFICIT - SPAIN	S&P - SPAIN	MOODY'S - SPAIN	FITCH - SPAIN
Mean	1.0315	0.4067	-4.1733	13.4556	13.1111	13.6000
Median	0.7633	0.6552	-3.0000	15.0000	15.0000	16.0000
Maximum	5.0741	15.4166	7.7000	17.0000	17.0000	17.0000
Minimum	0.0104	-17.4635	-24.8000	8.0000	8.0000	9.0000
Standard Dev.	1.1123	2.6556	5.9302	3.1379	3.7038	3.1969
Skewness	1.7166	-1.4722	-0.8654	-0.3396	-0.1047	-0.1712
Kurtosis	2.9340	33.8984	1.2061	-1.4614	-1.8572	-1.8263
Observations	90	90	90	90	90	90

Note: This table presents the descriptive statistics of whole sample size, which from Q1 2000 to Q2 2022. The descriptive statistics are rounded to four decimal places.
Source: Thomson Reuters Datastream; Federal Reserve Bank of St. Louis; Eurostat Datastream.

Table A2: Benchmark Models of PIIGS Countries

BOND SPREADS	Greece	Ireland	Italy	Portugal	Spain
C	1.9375***	−0.4046	0.0875	0.6662	−0.8986***
BOND SPREADS (-1)	0.7608***	0.9820***	0.9374***	0.9448***	1.0230***
ECB RATES	0.6604***	−0.0240	−0.0038	0.1330	−0.0791**
VSTOXX	0.0369*	−0.0051	0.0049	−0.0043	0.0060
HIGH GLOBAL RISK PERCEPTION	0.5246	0.3154**	0.1178	0.5939***	−0.0348
STANDARD & POOR	−0.4650***	0.0326	−0.0125	−0.0885	0.0677***

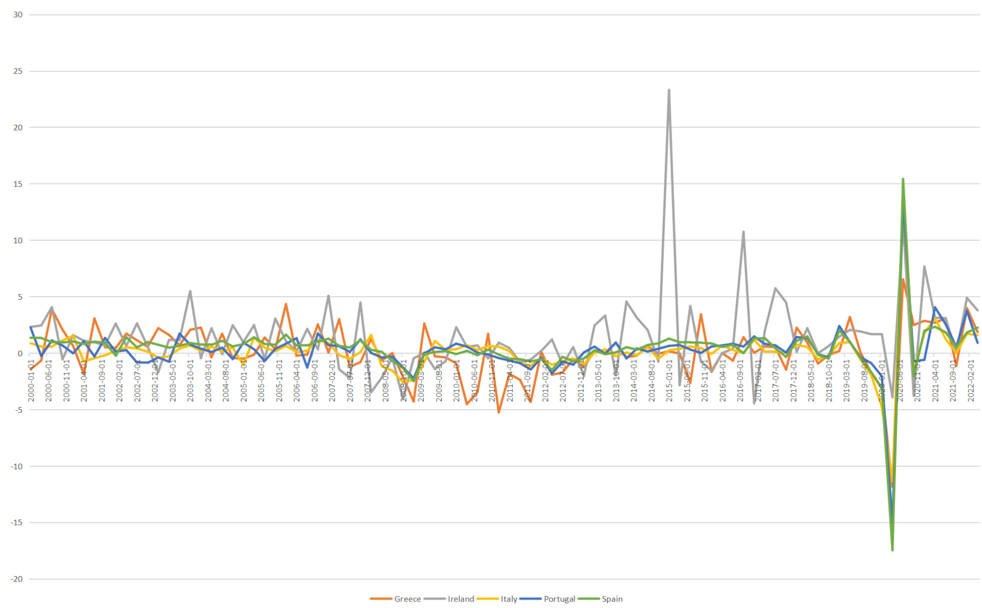
Note: This table presents the benchmark model which includes the whole sample data on PIIGS countries. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

Table A3: Credit Rating Transformation System

Characterization of debt and issuer (source: Moody's)		Rating			Linear transformation
		S&P	Moody's	Fitch	
Highest quality	Investment grade	AAA	Aaa	AAA	17
High quality		AA+	Aa1	AA+	16
		AA	Aa2	AA	15
		AA−	Aa3	AA−	14
Strong payment capacity		A+	A1	A+	13
		A	A2	A	12
		A−	A3	A−	11
Adequate payment capacity		BBB+	Baa1	BBB+	10
		BBB	Baa2	BBB+	9
		BBB−	Baa3	BBB−	8
Likely to fulfil obligations, onging uncertainty	Speculative grade	BB+	Ba1	BB+	7
		BB	Ba2	BB	6
		BB−	Ba3	BB−	5
High credit risk		B+	B1	B+	4
		B	B2	B	3
		B−	B3	B−	2
Very high credit risk		CCC+	Caa1	CCC+	1
		CCC	Caa2	CCC+	0
		CCC−	Caa3	CCC−	−1
Near default with possibility of recovery		CC	Ca	CC	−2
				C	−3
Default		SD	C	DDD	−4
		D		DD	−5
				D	−6

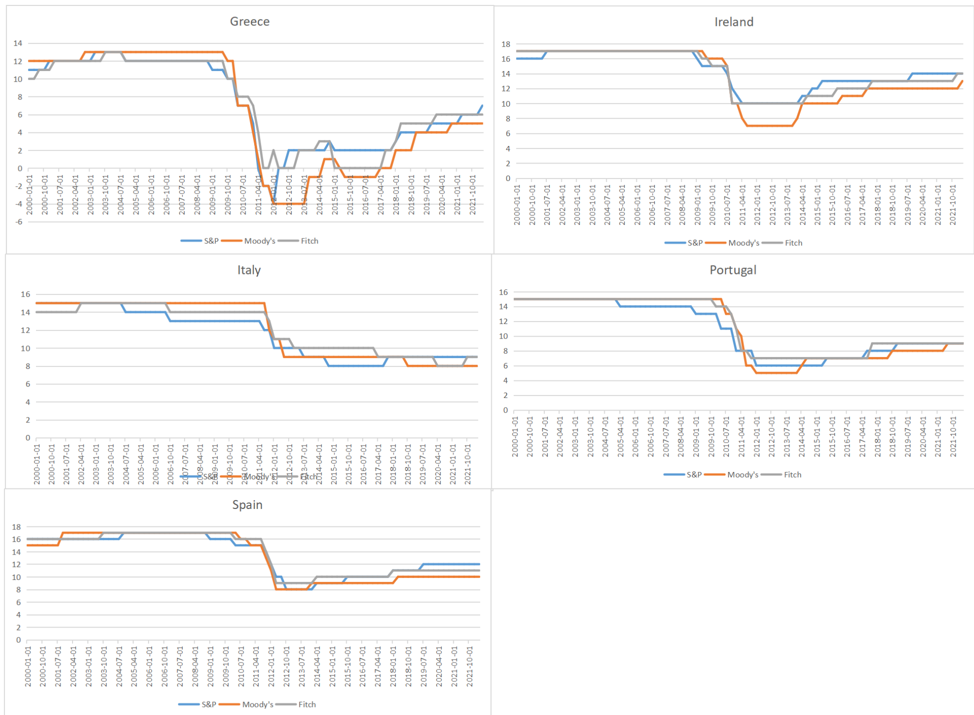
Note: This table presents the credit rating quantization system. The higher the number, the better the credit. The best performance number in this system is 17. The ratings above 7 are in the range of investment grade, and the ratings below 8 are in the range of speculative grade.
Source: Afonso et al.(2012).

Figure A1: GDP Growth Rates of PIIGS Countries



Note: This figure presnets the GDP growth rates of PIIGS countries from Q1 2000 to Q2 2022. The vertical axes indicate the GDP growth rates in percentage.
Source: Federal Reserve Bank of St. Louis; self-calculated.

Figure A2: Credit Ratings of Three Major Agencies



Note: This figure presnets the credit ratings of three major rating agencies on PIIGS countries from Q1 2000 to Q2 2022. The quantization of credit ratings in the vertical axes follows Afonso et al. (2012).
Source: Official website of Standard & Poor, Moody's and Fitch.

Table A4: Pairwise Correlation

GREECE	BOND SPREADS	ECB RATES	M3	VSTOXX	VIX	GDP GROWTH RATE	BUDGET DEFICIT	HIGH GLOBAL RISK	STANDARD & POOR	MOODY'S	FITCH	BAILOUT
BOND SPREADS	1.0000	-0.4808	-0.3998	-0.0089	-0.1268	-0.3042	-0.0840	-0.1870	-0.7988	-0.7834	-0.7553	0.7064
ECB RATES	-0.4808	1.0000	0.3842	0.1800	0.1521	0.1514	-0.1526	0.0529	0.8375	0.8185	0.8332	-0.2680
M3	-0.3998	0.3842	1.0000	0.0499	0.0880	0.0278	-0.0021	-0.0640	0.3699	0.3579	0.3331	-0.4702
VSTOXX	-0.0089	0.1800	0.0499	1.0000	0.8620	-0.1462	-0.3430	0.5828	0.2148	0.2423	0.2312	-0.0244
VIX	-0.1268	0.1521	0.0880	0.8620	1.0000	-0.2476	-0.2922	0.6928	0.2442	0.2915	0.2932	-0.0940
GDP GROWTH RATE	-0.3042	0.1514	0.0278	-0.1462	-0.2476	1.0000	0.1726	-0.0931	0.2140	0.1902	0.1759	-0.3020
BUDGET DEFICIT	-0.0840	-0.1526	-0.0021	-0.3430	-0.2922	0.1726	1.0000	-0.2476	-0.1378	-0.1495	-0.1932	-0.2592
BAILOUT	0.7064	-0.2680	-0.4702	-0.0244	-0.0940	-0.3020	-0.2592	-0.0226	-0.5433	-0.5512	-0.4494	1.0000
HIGH GLOBAL RISK	-0.1870	0.0529	-0.0640	0.5828	0.6928	-0.0931	-0.2476	1.0000	0.2158	0.2841	0.2862	-0.0226
STANDARD & POOR	-0.7988	0.8375	0.3699	0.2148	0.2442	0.2140	-0.1378	0.2158	1.0000	0.9761	0.9666	-0.5433
MOODY'S	-0.7834	0.8185	0.3579	0.2423	0.2915	0.1902	-0.1495	0.2841	0.9761	1.0000	0.9780	-0.5512
FITCH	-0.7553	0.8332	0.3331	0.2312	0.2932	0.1759	-0.1932	0.2862	0.9666	0.9780	1.0000	-0.4494

SPAIN	BOND SPREADS	ECB RATES	M3	VSTOXX	VIX	GDP GROWTH RATE	BUDGET DEFICIT	HIGH GLOBAL RISK	STANDARD & POOR	MOODY'S	FITCH
BOND SPREADS	1.0000	-0.6712	-0.3867	-0.0610	-0.0426	-0.1424	0.0299	-0.1302	-0.6238	-0.6134	-0.5837
ECB RATES	-0.6712	1.0000	0.3842	0.1800	0.1521	-0.0071	0.0816	0.0529	0.9049	0.8638	0.8784
M3	-0.3867	0.3842	1.0000	0.0499	0.0880	-0.1137	-0.0149	-0.0640	0.1691	0.1143	0.0925
VSTOXX	-0.0610	0.1800	0.0499	1.0000	0.8620	-0.1389	-0.0870	0.5828	0.2988	0.2837	0.2625
VIX	-0.0426	0.1521	0.0880	0.8620	1.0000	-0.2274	-0.1372	0.6928	0.2808	0.2650	0.2062
GDP GROWTH RATE	-0.1424	-0.0071	-0.1137	-0.1389	-0.2274	1.0000	-0.0127	-0.0018	0.0057	-0.0084	-0.0199
BUDGET DEFICIT	0.0299	0.0816	-0.0149	-0.0870	-0.1372	-0.0127	1.0000	-0.2366	0.0255	0.0524	0.0965
HIGH GLOBAL RISK	-0.1302	0.0529	-0.0640	0.5828	0.6928	-0.0018	-0.2366	1.0000	0.3230	0.2611	0.1646
STANDARD & POOR	-0.6238	0.9049	0.1691	0.2988	0.2808	0.0057	0.0255	0.3230	1.0000	0.9451	0.9393
MOODY'S	-0.6134	0.8638	0.1143	0.2837	0.2650	-0.0084	0.0524	0.2611	0.9451	1.0000	0.9782
FITCH	-0.5837	0.8784	0.0925	0.2625	0.2062	-0.0199	0.0965	0.1646	0.9393	0.9782	1.0000

ITALY	BOND SPREADS	ECB RATES	M3	VSTOXX	VIX	GDP GROWTH RATE	BUDGET DEFICIT	HIGH GLOBAL RISK	STANDARD & POOR	MOODY'S	FITCH
BOND SPREADS	1.0000	-0.6712	-0.3867	-0.0610	-0.0426	-0.1424	0.0299	-0.1302	-0.6238	-0.6134	-0.5837
ECB RATES	-0.6712	1.0000	0.3842	0.1800	0.1521	-0.0071	0.0816	0.0529	0.9049	0.8638	0.8784
M3	-0.3867	0.3842	1.0000	0.0499	0.0880	-0.1137	-0.0149	-0.0640	0.1691	0.1143	0.0925
VSTOXX	-0.0610	0.1800	0.0499	1.0000	0.8620	-0.1389	-0.0870	0.5828	0.2988	0.2837	0.2625
VIX	-0.0426	0.1521	0.0880	0.8620	1.0000	-0.2274	-0.1372	0.6928	0.2808	0.2650	0.2062
GDP GROWTH RATE	-0.1424	-0.0071	-0.1137	-0.1389	-0.2274	1.0000	-0.0127	-0.0018	0.0057	-0.0084	-0.0199
BUDGET DEFICIT	0.0299	0.0816	-0.0149	-0.0870	-0.1372	-0.0127	1.0000	-0.2366	0.0255	0.0524	0.0965
HIGH GLOBAL RISK	-0.1302	0.0529	-0.0640	0.5828	0.6928	-0.0018	-0.2366	1.0000	0.3230	0.2611	0.1646
STANDARD & POOR	-0.6238	0.9049	0.1691	0.2988	0.2808	0.0057	0.0255	0.3230	1.0000	0.9451	0.9393
MOODY'S	-0.6134	0.8638	0.1143	0.2837	0.2650	-0.0084	0.0524	0.2611	0.9451	1.0000	0.9782
FITCH	-0.5837	0.8784	0.0925	0.2625	0.2062	-0.0199	0.0965	0.1646	0.9393	0.9782	1.0000

PORTUGAL	BOND SPREADS	ECB RATES	M3	VSTOXX	VIX	GDP GROWTH RATE	BUDGET DEFICIT	HIGH GLOBAL RISK	STANDARD & POOR	MOODY'S	FITCH	BAILOUT
BOND SPREADS	1.0000	-0.4106	-0.4147	0.0118	-0.0667	-0.1401	-0.2087	-0.0976	-0.6505	-0.6427	-0.6209	0.8279
ECB RATES	-0.4106	1.0000	0.3842	0.1800	0.1521	-0.0327	-0.0658	0.0529	0.8909	0.8463	0.8671	-0.1961
M3	-0.4147	0.3842	1.0000	0.0499	0.0880	-0.1536	0.1895	-0.0640	0.3432	0.2843	0.2689	-0.3473
VSTOXX	0.0118	0.1800	0.0499	1.0000	0.8620	-0.1952	-0.2658	0.5828	0.2580	0.2659	0.2611	-0.0171
VIX	-0.0667	0.1521	0.0880	0.8620	1.0000	-0.2323	-0.1632	0.6928	0.2926	0.2882	0.2957	-0.0849
GDP GROWTH RATE	-0.1401	-0.0327	-0.1536	-0.1952	-0.2323	1.0000	0.1930	-0.0364	0.0120	0.0139	-0.0008	-0.1255
BUDGET DEFICIT	-0.2087	-0.0658	0.1895	-0.2658	-0.1632	0.1930	1.0000	-0.2139	-0.0540	-0.1439	-0.1275	-0.1516
BAILOUT	0.8279	-0.1961	-0.3473	-0.0171	-0.0849	-0.1255	-0.1516	-0.1284	-0.4765	-0.5188	-0.4608	1.0000
HIGH GLOBAL RISK	-0.0976	0.0529	-0.0640	0.5828	0.6928	-0.0364	-0.2139	1.0000	0.2870	0.3014	0.2810	-0.1284
STANDARD & POOR	-0.6505	0.8909	0.3432	0.2580	0.2926	0.0120	-0.0540	0.2870	1.0000	0.9682	0.9761	-0.4765
MOODY'S	-0.6427	0.8463	0.2843	0.2659	0.2882	0.0139	-0.1439	0.3014	0.9682	1.0000	0.9848	-0.5188
FITCH	-0.6209	0.8671	0.2689	0.2611	0.2957	-0.0008	-0.1275	0.2810	0.9761	0.9848	1.0000	-0.4608

IRELAND	BOND SPREADS	ECB RATES	M3	VSTOXX	VIX	GDP GROWTH RATE	BUDGET DEFICIT	HIGH GLOBAL RISK	STANDARD & POOR	MOODY'S	FITCH	BAILOUT
BOND SPREADS	1.0000	-0.2885	-0.4537	0.1369	0.1297	-0.1438	-0.5946	0.1950	-0.6696	-0.6059	-0.5969	0.8372
ECB RATES	-0.2885	1.0000	0.3842	0.1800	0.1521	-0.1481	0.1964	0.0529	0.7846	0.7798	0.8264	-0.1968
M3	-0.4537	0.3842	1.0000	0.0499	0.0880	0.0090	0.5146	-0.0640	0.4706	0.3762	0.4013	-0.3574
VSTOXX	0.1369	0.1800	0.0499	1.0000	0.8620	-0.1632	-0.2658	0.5828	0.1946	0.2074	0.2183	-0.0139
VIX	0.1297	0.1521	0.0880	0.8620	1.0000	-0.2047	-0.2962	0.6928	0.2302	0.2538	0.2688	-0.0697
GDP GROWTH RATE	-0.1438	-0.1481	0.0090	-0.1632	-0.2047	1.0000	0.1410	-0.0647	-0.0753	-0.0747	-0.0960	-0.1410
BUDGET DEFICIT	-0.5946	0.1964	0.5146	-0.2658	-0.2962	0.1410	1.0000	-0.4674	0.2839	0.1809	0.2385	-0.3839
BAILOUT	0.8372	-0.1968	-0.3574	-0.0139	-0.0697	-0.1410	-0.3839	-0.0221	-0.6824	-0.6687	-0.6132	1.0000
HIGH GLOBAL RISK	0.1950	0.0529	-0.0640	0.5828	0.6928	-0.0647	-0.4674	1.0000	0.1607	0.2177	0.1958	-0.0221
STANDARD & POOR	-0.6696	0.7846	0.4706	0.1946	0.2302	-0.0753	0.2839	0.1607	1.0000	0.9732	0.9717	-0.6824
MOODY'S	-0.6059	0.7798	0.3762	0.2074	0.2538	-0.0747	0.1809	0.2177	0.9732	1.0000	0.9836	-0.6687
FITCH	-0.5969	0.8264	0.4013	0.2183	0.2688	-0.0960	0.2385	0.1958	0.9717	0.9836	1.0000	-0.6132

Note: This table presnets the pairwise correlation of applied variables. To avoid high correlation (≥ 0.8) variables in one regression, we have 9 regressions and one robust test regression.
Source: Eviews 8 outputs.

Table A5: Robustness Tests of PIIGS Countries

BOND SPREADS	**GREECE**	**IRELAND**	**ITALY**	**PORTUGAL**	**SPAIN**
C	0.8853	-0.0818	0.2361	0.0478	-0.3663*
	(0.6212)	(0.4493)	(0.2536)	(0.3437)	(0.2096)
BOND SPREADS (-1)	0.8334***	0.9096***	0.9306***	0.9677***	1.0028***
	(0.0504)	(0.0444)	(0.0429)	(0.0380)	(0.0383)
VSTOXX	0.0325	-0.0069	0.0026	-0.0062	0.0026
	(0.0225)	(0.0070)	(0.0050)	(0.0096)	(0.0041)
STANDARD & POOR	-0.1657***	0.0121	-0.0183	-0.0079	0.0211
	(0.0547)	(0.0300)	(0.0182)	(0.0267)	(0.0137)
GDP GROWTH RATE	-0.1008	-0.0043	-0.0363**	-0.0245	-0.0205*
	(0.0653)	(0.0132)	(0.0166)	(0.0281)	(0.0119)
BUDGET DEFICIT	-0.0268	-0.0223***	0.0127	-0.0144	-0.0020
	(0.0274)	(0.0071)	(0.0083)	(0.0174)	(0.0067)
HIGH GLOBAL RISK PERCEPTION	0.1485	0.2723**	0.1727*	0.4674***	0.0676
	(0.3927)	(0.1365)	(0.0912)	(0.1656)	(0.0767)
OBSERVATION	90	90	90	90	90
R-SQUARED	0.9339	0.9476	0.9139	0.9437	0.9461

Note: We drop two variables in this table as the robustness test- credit rating and high global risk perception, as they represent high correlation with interest rates and VIX index. Standard errors are in the brackets. *** indicates 99% significance level; ** indicates 95% significance level; and * indicates 90% significance level. The results are rounded to four decimal places.
Source: Eviews 8 outputs.

Chapter 3

HOW DO MONETARY POLICY AND OTHER DETERMINANTS SHOCKS AFFECT PERIPHERY COUNTRIES' SOVEREIGN CREDIT DEFAULT SWAP SPREADS IN THE EUROZONE?

Abstract

In this chapter, we focus on the impacts of European Central Bank's monetary easing policy on the European periphery sovereign risk markets during and after the Global Financial Crisis and European sovereign debt crisis. Our results are mainly based on the impulse response functions and Granger causality tests. The non-linear Granger causality tests, in particular, employing a vector autoregressive neural network approach, are used for the first time in sovereign credit market analysis. Our study demonstrates that the ECB's interest rate reduction policy effectively reduced the sovereign credit risk of the five peripheral countries during the crisis period, but not in the post-crisis period. Additionally, the outputs confirm the relationships between shocks of the stock market, liquidity patterns, macro-fundamentals, and the level of sovereign risks.

3.1 Introduction

The Credit Default Swap (CDS) was introduced by JP Morgan in 1994 and has since been traded over-the-counter (OTC) as a credit derivative. The market for CDS experienced significant growth, particularly after 2000, reaching a peak of 62 trillion dollars by the end of 2007. However, the market began to decline after the Global Financial Crisis (GFC) of 2007-2009 and Lehman's bankruptcy, with the market size falling to 26.3 trillion dollars in 2010. CDS contracts are typically executed based on standard documents provided by the International Swaps and Derivatives Association (ISDA), with counterparties agreeing on credit events and other contractual terms. These contracts allow investors to bet on whether a debt will default, with protection buyers paying a spread fee, quoted as a percentage of the insured amount, denominated in basis points and indicating the annual premium. Premiums persist until the contract expires or the credit event occurs. Sovereign CDS contracts, a subset of CDS contracts that allows traders to transact in government bonds, had an outstanding market size of 1530 billion USD, accounting for 16% of the CDS global market in the second quarter of 2017. Although governments cannot go bankrupt like corporations at the sovereign level, a credit event can still occur, as evidenced by the Greek government's default in April 2012 and the Argentine credit event in August 2014. Trading sovereign CDS during a crisis is a common strategy for investors to hedge their risks against any obligation in a government bond. However, the role of CDS remains controversial, as naked CDS/footnoteNaked CDS refer to holdings of credit default swaps that lack adequate backing from the corresponding underlying asset. buyers were accused of speculating on government bond defaults and artificially driving up their borrowing costs during the sovereign default periods of Greece and Argentina (Augustin et al., 2014). Despite its widespread use, the CDS market remains largely unregulated, with sellers not required to hold reserves against

CDS default, exacerbating the potential risks associated with the market.

Sovereign CDS spreads are important indicators of countries' risk perception. In July 2008, at the time of IndyMac's collapse, Greece's sovereign CDS spread was 49.75 basis points. However, in April 2010, Greece's announcement of a significant revision of its reported government deficit for 2009 caused a loss of investor confidence in its sovereign debt market. Consequently, the spreads skyrocketed to an unprecedented 37,030.49 in March 2012, indicating a substantial loss of market confidence. This led to Greece's sovereign CDS going into debt restructuring, which triggered the European debt crisis. This crisis affected other peripheral European countries, with Italy, Ireland, Spain, and Portugal experiencing the least stability and being the primary sufferers. In May 2013, Spain and Greece had high unemployment rates of 26.9% and 26.8%, respectively. Since 2010, the Troika, comprising the International Monetary Fund, European Commission, and European Central Bank (ECB), has provided bailouts in the form of direct capital injections, asset purchase programs, and debt guarantees. The ECB has persistently decreased key policy interest rates during the crisis, also unconventional monetary policy. This policy applied to each Eurozone country, as the European area's economic and monetary union was established to share a single monetary policy and currency in 1999. After Greece joined the Eurozone, the euro became its sole legal currency in 2002. Several empirical studies have found that the ECB's actions achieved their aims, as the monetary policies during past crises aimed to control inflation levels, and price stability remained within medium to long-term expectations (Hartmann & Smets, 2018). Furthermore, easing monetary policies improved the condition of CDS spreads during low-interest rate periods (Altavilla et al., 2018). As the monetary policy shocks, which are the surprise element of monetary policy given rational expectations of agents assumed, plays a vital role of transmitting shocks effects to other markets (i.e. stock markets). However, as a financial derivative, CDS is particularly sensitive to changes in external factors. Therefore, it is critical for investors to hold stable and predictable CDS contracts. Additionally, sovereign CDS is generally believed to reflect the country's investment risk level, which makes the sovereign CDS spread itself non-negligible. Investors tend to choose countries with lower spreads and smaller variances in sovereign CDS in their portfolios. It can also be seen from this point that when the government formulates policies, it is necessary to consider the consequences of policies on sovereign CDS.

This chapter aims to address the following research questions: How do ECB monetary policy shocks affect sovereign CDS spreads in European periphery countries? How do other potential shocks impact sovereign CDS spreads in different periods? Are the determinants the same for all five periphery countries? There is a scarcity of literature studying the relationship between the ECB's monetary policy and Eurozone sovereign credit default swap spreads. By examining the behavior of CDS spread fluctuations impacted by monetary policy shocks, market liquidity, and macroeconomic shocks, this research aims to provide insights for sovereign issuers, banks, and individual investors.

3.2 Literature Review

To comprehend the determinants of sovereign CDS spreads, Duffie (1999) developed a non-arbitrage model within the asset pricing sub-branch of credit sovereign swap spreads. This model established a correspondence between a portfolio comprising a default-free and defaultable floating-rate bond. Through analysis of the investment trade-off strategies of CDS contract buyers and sellers, Duffie (1999) concludes that the absence of arbitrage necessitates that CDS spreads must cover the risk-free rate. While acknowledging that this theoretical model is not without limitations, it provides an important framework for measuring and applying default probabilities and recoveries. Despite the significance of the arbitrage-free model, Hull and White (2000) propose an alternative approach for valuing default probabilities on financial derivatives through Monte Carlo simulation, using the factor copula model. This method provides an additional means of valuing default probability on financial derivatives, but in the case of sovereign CDS, defaults become more complex. Nonetheless, past arbitrage models can still provide valuable insights. From Duffie's (1999) work, it can be inferred that, aside from short-term fluctuations, CDS spreads are significantly affected by the risk-free rate in the long run. Thus, an important research question to consider is how the risk-free rate affects sovereign CDS spreads.

The determination of credit risk has been the subject of empirical research for several decades, with Merton's (1974) introduction of a structural model for risky corporate debt being an early example. However, sovereign default presents a more complex scenario. While Bedendo and Colla (2015) have confirmed and analyzed the relationship between sovereign and corporate CDS, highlighting the existence of a contagion mechanism between sovereign and corporate credit, they have also shown that sovereign CDS spreads are largely determined and impacted by exogenous factors. Unlike the corporate level, a government cannot default by a standard criterion but can strategically default at its discretion (Augustin, 2014). Pre-GFC literature demonstrates that, by applying daily data for Mexico, Turkey, and Korea, the risk premia of CDS spreads are related to global event risk, financial market liquidity, and macroeconomic policies (Pan and Singleton, 2008). In the aftermath of the crisis, the importance of US stock markets for global sovereign CDS volatility has been emphasized in the literature. Longstaff et al. (2011) found that sovereign credit is driven by three major components: US stock and high yield bond markets, global risk premia, and international trading and liquidity patterns. Their regression results from 26 emerging markets confirm the dominance of the US financial market through a multivariate GARCH model. Wang and Moore (2012) suggested that the world's largest market, the US, has heavily influenced emerging CDS markets during the crisis as a spillover effect. Fender et al. (2011) arrived at the same conclusion by using the GARCH model on daily data from 2002 to 2011.

The literature on global emerging markets has relied on the spillover effect of US stock market volatility as a measure of global risk. This finding has also been observed in European markets. Research by Favero et al. (2010) confirms that the US stock market's volatility index is the primary driver of the euro area sovereign spreads. However, Ang and Longstaff (2013) conducted a comparative study of sovereign credit risk between the US and Europe and found that American credit risk has a significant negative correlation with the Chicago stock market index, whereas Eurozone systemic risk does not. These results suggest that European credit risk is more likely to be linked to domestic stock market perception compared to the US stock market. De Santis (2014) conducted a similar study by employing the local regional factors, which confirmed the insignificant impact of US stock market volatility on Eurozone countries. The post-crisis literature points out that the creditworthiness of the Eurozone is more susceptible to local fluctuations in Europe than the US stock market. However, the above literature has significant limitations. Ang and Longstaff's (2013) study did not find significant evidence linking the European stock market volatility index with sovereign CDS in the Eurozone. Similarly, De Santis (2014) used the estimated KfW - Bund index as a systemic risk to replace the US stock market index, but the European stock market volatility was not included in the model. This chapter aims to fill this gap by using the European stock market index as a measure of systemic risk for investigating the relationship between European stock market shocks and sovereign CDS in peripheral countries. The stock market is a rapidly changing sector that investors are highly concerned about. Therefore, if changes in the stock market significantly affect the volatility of sovereign CDS spreads, it would provide additional value for medium and long-term investment strategies.

The liquidity of sovereign CDS in the Eurozone is a crucial factor in their determination. While Longstaff et al.'s (2011) findings are not entirely applicable to the Eurozone, previous studies have established the significance of sovereign market liquidity on spreads, which vary over time and across countries. Calice et al. (2013) focused on various Eurozone periphery countries and discovered the significant impact of sovereign market liquidity on spreads, with varying effects over time. Similarly, Galariotis et al. (2016) utilized a panel vector autoregressive model and discovered that the determinants of CDS spreads differ across countries and periods, with investor sentiment focused on larger economies such as Spain and Italy. We hypothesize that the impact of liquidity during the crisis period is greater than during non-crisis periods, as analyzed by Beber et al. (2009), and that liquidity effects vary across countries. Specifically, Beber et al. (2009) and Calice et al. (2013) use bid-ask spreads as a variable for liquidity. Galariotis et al. (2016) used the 3-month Euribor-Eonia spread[1] to measure liquidity. In this chapter, we use the bid-ask spreads of sovereign CDS as the liquidity variable, which may be more targeted. Furthermore, our larger sample size will provide a more comprehensive view of research results across time.

In addition to the aforementioned determinants of CDS, Fontana and Scheicher (2016) propose that while bond spreads and CDS are influenced by the same risk factors, sovereign CDS are also related to the individual credit risk of the country. Empirical analyses that use different methodologies, such as Tang and Yan (2010), Brandorf and Holmberg (2010), and Can and Paskaleva (2017), demonstrate that macroeconomic variables like GDP growth rate, current account balance, inflation level, and unemployment rate have a significant impact on sovereign CDS. These findings indicate that an inclusive evaluation of the determinants of sovereign CDS should consider both global and local factors that affect credit risk. In this chapter, we will augment our analysis by incorporating macroeconomic factors as control variables, in addition to monetary policy variables. Moreover, the magnitude of the impact of changes in macroeconomic variables across various countries on sovereign CDS can shed light on the relevance of systemic risk in sovereign credit.

The impact of monetary policy on sovereign CDS spreads has been extensively studied in the literature. Fender et al. (2011) report that US monetary policy significantly affects emerging sovereign credit markets, including European emerging countries. Similarly, Spyrou (2018) concludes that the ECB's both conventional and unconventional monetary policies during the crisis have a significant negative impact on CDS spreads and bond yields, which reduces market uncertainty and riskiness of investments. On the one hand, Pattipeilohy et al. (2013) suggest

[1] The Euro OverNight Index (Eonia) is the 1-day interbank interest rate for the Euro zone, in other words it may be thought of as the 1 -day Euribor rate. The difference between the 3-month Euribor and the 3-month Eonia rate is employed.

that the effects of unconventional monetary policies, such as extended liquidity provision and securities market program, only effects in short-term and last for only a few weeks. Cukierman (2012) finds that interest rate adjustment-based monetary policy is less effective during crisis periods, based on Federal Reserve and ECB data. On the other hand, Fender et al. (2011) find that, although local factors play a crucial role in determining CDS spreads before the crisis, the US and Europe monetary decisions are more important to CDS volatility than country-specific factors after the crisis. The discussion of monetary policy shocks mainly focuses on the impact on the stock market. Most of the literature has provided evidence for the negative response of the stock market to monetary policy shocks (Chatziantoniou, Duffy and Filis, 2013). As mentioned in the previous paragraph, the stock market and the sovereign CDS market are closely related. Therefore, we assume that sovereign CDS markets would be negatively response to monetary policy shocks. Additionally, Drakos and Kouretas (2015) argue that a structural break occurred during the peak of the Eurozone financial crisis, and the authorities were more passive in the post-crisis period and more active during the financial turmoil, through a Markov-Switching VAR process. Despite the evidence suggesting a difference in the effectiveness of unconventional policies between crisis and non-crisis periods, the more efficient policy period remains controversial. To further analyze the impacts of monetary policy shocks on sovereign CDS, this chapter aims to expand the sample size of the post-crisis period and identify the different effects of monetary policy shocks during the crisis and post-crisis periods. We hypothesize that there will be a more negative and significant effect of monetary policy shocks on sovereign CDS spreads during the crisis period.

Upon review of previous literature, it has been observed that the variability of sovereign CDS is largely influenced by systemic risk. The ECB's unified monetary policy, in addition to stock market volatility, is another key factor that affects sovereign CDS shocks. Previous studies have repeatedly highlighted the systemic risk posed by the volatility of the US stock market in their analysis of the factors influencing sovereign CDS. However, this does not apply to all Eurozone countries and different periods, which is why this chapter utilizes the European stock market index and undertakes a comparative analysis of different periods to supplement previous research. In terms of market liquidity, this chapter uses sovereign CDS bid-ask spreads and increases the sample size to ensure more generalizable results, especially for research in the post-crisis period. The literature and models on systematic risk research often lack an analysis of fundamental risks, which is why macroeconomic variables are included in this chapter's main research question. Additionally, the significance of macroeconomic variables on sovereign CDS can demonstrate the ability to resist external risk shocks to a certain extent. Finally, past literature has been contentious on the effectiveness of the ECB's sovereign credit policy to the Eurozone countries during different periods. By extending the time horizon of the post-crisis period, this section aims to demonstrate the effectiveness of the ECB's monetary policy over various periods.

3.3 Methodologies

The use of the vector autoregressive (VAR) model in monetary policy studies is a common practice. Fernández-Amador et al. (2013), for instance, employed the VAR model to analyze the relationship between monetary policy and market liquidity, taking into account endogeneity issues. Similarly, in this chapter, we adopt the VAR model to investigate the link between monetary policy and the sovereign CDS market while considering potential endogeneity. Furthermore, Granger causality analysis enables us to shed more light on the research questions. While Granger causality has also been used by Galariotis et al. (2016), Calice et al. (2013), and Kalbaska and Gatkowski (2012) in their studies of sovereign CDS determinants, their research concentrates more on the contagion effects of the sovereign credit market and lacks monetary policy variables in their models. By incorporating monetary policy variables into our VAR model, we aim to examine the influence of monetary policy shocks on sovereign CDS spreads in different periods.

In this chapter, we adopt the variable selection approach utilized in previous CDS asset pricing models. The first such model was developed by Duffie (1999), who decomposed the term structure of credit swap's constant hazard rate. This model was subsequently refined by Longstaff et al. (2011) and embedded into a macro framework by Augustin and Tedongap (2016), which demonstrated that the term structure components of CDS spreads could be represented as an expectation of recovery rate, households' risk perception, and hazard rate. Given that risk perception is correlated with numerous financial indexes, we use the VSTOXX and bid-ask spreads in this chapter. The hazard rate, on the other hand, is impacted by expected economic growth and consumption volatility. Given the multidimensional impact of monetary policy on both the financial and the overall economy, a VAR model is utilized to assess the relationship between monetary policy shocks and sovereign CDS shocks in the financial market. We utilize six variables, namely CDS spreads, bid-ask spreads, VSTOXX index, industrial production, ECB rates, and M3 growth rate.

In this study, we employ five sovereign CDS spreads in five separate VAR models, namely Italy, Ireland, Portugal, Spain, and Greece. Sovereign CDS spreads represent a form of insurance contract against any credit event of a specific government on its debt, such as a failure to meet repayment obligations or a debt reconstruction. The spreads are measured in percentage terms of the notional amount that protection buyers pay the protection seller annually. As CDS spreads are determined by the secondary market, they tend to vary over time. As one of the most widely used credit derivatives, CDS contracts are extensively used for arbitrage investment in hedge funding. Specifically, we use 5-year maturity CDS spreads in our models.

The bid-ask spread is a commonly used measure of liquidity for financial derivative products. It reflects the difference between the bid and ask prices[2] of a specific sovereign CDS contract in the secondary market. A wider bid-ask spread generally indicates lower liquidity and higher risk. Bid-ask spreads have been used as a liquidity variable in previous studies such as Beber et al. (2009) and Calice et al. (2013). In this chapter, we collect bid-ask spreads for five countries with 5-year maturity CDS contracts. We assume that higher bid-ask spreads may be associated with higher sovereign CDS spreads, reflecting the potential impact of liquidity on the level of risk in the financial market.

The VSTOXX index is derived from the EURO STOXX 50 and reflects market expectations of near-term to long-term volatility by measuring the square root of the implied variance. Both VIX and VSTOXX indices are introduced and em-

[2]Bid price: the highest price that buyer wishes to pay; ask price: the lowest price that seller could accept.

ployed in Chapter 2. The findings in Chapter 2 reveal that the VSTOXX index is more closely related to the sovereign credit of peripheral European countries than the VIX. An increase in the VSTOXX signals a greater likelihood of market panic, leading to risk-averse behavior by investors. Historical data shows that the VSTOXX increased during the financial crisis, during which investors were more likely to withdraw their capital from markets with low liquidity. Additionally, fear can directly impact CDS spreads by altering financiers' perceptions. A rise in the VSTOXX index may lead to negative prospects for the Eurozone market in the eyes of investors. The VSTOXX index is used as a substitute for the US stock market index, comparing to past research such as Favero et al. (2010) and Ang and Longstaff (2013).

In addition to the aforementioned factors, macroeconomic variables are also important in analyzing the impact of monetary policy shocks on sovereign CDS spreads. One such variable is industrial production, which represents the output of the industrial sector of a country and is a key component of its GDP. This variable is chosen due to its association with the underlying strength of the country's economy and its relative independence from the financial market. Typically, higher levels of industrial production are associated with a more stable and less risky market, and thus, we assume that a shock to industrial production would lead to a negative response in sovereign CDS spreads. Incorporating such macroeconomic variables into the model can help provide a more comprehensive understanding of the factors that influence sovereign CDS spreads.

The variable selection for the ECB monetary policy in this study includes two variables: interest rates and monetary aggregates. To avoid multicollinearity, we set two variable groups to distinguish different monetary adjustment effectiveness - the details will be introduced in 3.3.1. The ECB sets three key interest rates for the Eurozone: the main refinancing operations rate, the deposit facility rate, and the lending facility rate. In this study, we employ the overnight deposit rate as a key indicator of European monetary policy. It is worth noting that central banks' interest rate reduction is generally regarded as a symbol of liquidity release, which enhances the overall economic performance. Apart from controlling the risk-free deposit rate, the authorities can restrict the market money issuing amount to apply monetary policy - especially after the nominal rates hit the zero, lower bound and quantitative easing became a widely-used addition to monetary policy following the GFC. M3 (monetary aggregate 3) represents all local currency in circulation, including demand deposits, saving deposits, and other least liquid components of the money supply. M3 is included in the models to control for predictable inflation in the long-term.

3.3.1 Vector Autoregressive Model

The VAR model is a multivariate autoregressive model that is suitable for analyzing multiple time series, and is particularly relevant to the objectives of this research. Each endogenous variable in the model is a linear function of its own lagged values as well as the lagged values of other variables in the system. In this study, we estimate five VAR models for five different countries, with VSTOXX and ECB rates (M3) held constant across all countries, and the other three variables being specific to each country. A typical representation of a VAR model is as follows[3]:

$$\begin{aligned} CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} \\ + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t} \end{aligned} \quad (3.1)$$

[3] INTEREST is substituted to MONETARY as the measurement of monetary aggregate in M3 models.

To estimate the VAR models for each country, we include the sovereign CDS spreads as endogenous variables, while the interest rate variable is replaced with the monetary aggregate as a control group. The optimal lag length, denoted as n, is determined based on the Schwarz criterion (SC) and Akaike information criterion (AIC). Specifically, the optimal lag length is selected to minimize these criteria and improve the model's performance.

The impulse response function (IRF) is a useful tool for analyzing how each variable reacts to shocks in the system. When variables are interdependent, individual coefficients may not provide a complete picture of the information. To get a better picture of the model's dynamic behaviour, we employ the forecast error impulse response (FEIR) function in this chapter, which has the departure point of every IRF for a linear VAR model is its moving average (MA) representation.

In addition, we will test for Granger Causality between the interest rate and CDS spreads. The F statistic will be calculated for both the restricted and unrestricted functions to obtain the result, as follows:

$$CDS_{i,t} = \sum_{j=1}^{\infty} \phi_i CDS_{i,t-j} + c_1 + v_{1,t} \tag{3.2}$$

$$CDS_{i,t} = \sum_{j=1}^{\infty} \phi_i CDS_{i,t-j} + \sum_{k=1}^{\infty} \varphi_i Interest_{i,t-k} + c_2 + v_{2,t} \tag{3.3}$$

To ensure the suitability of the VAR model and Granger causality analysis, it is necessary to verify the stationarity of the time series. This is achieved using the augmented Dickey-Fuller test, which is applied to each variable included in the analysis. For instance, the null hypothesis of the test for the sovereign CDS variable is that the series contains at least one unit root, i.e., γ=0. Only stationary time series can provide reliable results and meaningful conclusions in this context:

$$\triangle CDS_{i,t} = \alpha^a + \beta^a_{i,t} + \gamma CDS_{i,t-1} + \sigma_1 \triangle CDS_{i,t-1} + \sigma_2 \triangle CDS_{i,t-2} + ... + \sigma_p \triangle CDS_{i,t-p} \tag{3.4}$$

3.3.2 Vector Autoregressive Neural Network Model

This study employs an extended Granger causality test based on the Vector Autoregressive Neural Network (VARNN) model, which is an Artificial Neural Network (ANN)-assisted VAR model. The VARNN model is capable of analyzing Granger causality relationships between non-linear time series and possesses stronger prediction abilities than traditional VAR models (Pendar & Haji, 2017). In this study, we aim to test the response of sovereign CDS to shocks of other factors by applying the VARNN model as a robustness test of the Granger causality test. The VARNN(p) model comprises predictor variables with lag p and the target variable Y to predict future values of Y. In this model, the data is based on the lag parameter, and the weights of the network are calculated using the stochastic gradient descent (SGD) algorithm, which is employed as an optimization algorithm. Notably, no research has been conducted to apply the VARNN model to the CDS market to date. A brief representation of the VARNN(p) model is as follows, where Ψ_{nn} indicates the network function, and U_t is the error term:

$$Y_t = \Psi_{nn}(Y_{t-1}, ..., Y_{t-p}, ..., Y_{k(t-1)}, ..., Y_{k(t-p)}) + U_t \tag{3.5}$$

Similarly to the conventional Granger Causality test, the evaluation of non-linear Granger causality can be accomplished by computing the Fisher statistic between two models, restricted and unrestricted. Nevertheless, compared to the standard approach, the non-linear test employs a modified algorithm of the Fisher statistic, as VARNN models possess a greater number of parameters than VAR models. The refined statistic function can be expressed as follows:

$$F = \frac{(RSS_1 - RSS_2)/(d_2 - d_1)}{RSS_2/(n - d_2)} \tag{3.6}$$

The d_1 and d_2 are the number of parameters, which were determined by the chosen structure of included layers and neurons in the unrestricted and restricted models respectively.

3.4 Data

The dataset used in this study consists of monthly time series data spanning from July 2008 to December 2017, sourced from Bloomberg terminal and Federal Reserve Bank of St. Louis database. The sample period is split into two sub-periods: the crisis period (July 2008 to September 2014) and the post-crisis period (October 2014 to December 2017). The period division is based on significant events such as the failure of IndyMac in July 2008, which marked the beginning of the US financial crisis, and the start of the European sovereign debt crisis in Greece in 2009. In April 2012, Greece's government defaulted, and its sovereign CDS has been available in the market for more than a year (see in Appendix B, Figure B1). Greece entered the sovereign CDS market with spreads of 727.78 in October 2014, and Moody's and S&P upgraded Greek sovereign ratings in August and September 2014. The first part of the sample data is considered a "crisis period", given the contagion effects observed among EMU countries. In contrast, the post-crisis period is characterized by relative stability, despite the ongoing instability of Greek sovereign CDS and sovereign credit ratings and a selective default in Argentine from 2014 to 2016. The models developed for the five countries are used as benchmarks for linear and non-linear Granger causality analysis, and the variables are simplified based on the results from the sub-period models.

Table B1, B2 and B3 (in Appendix B) presents the descriptive statistics and Augmented Dickey-Fuller (ADF) test results for the variables under consideration, are separated in crisis and post-crisis period respectively. The industrial production series was found to have unit roots and was made stationary by taking log-differences. Most countries' CDS series were non-stationary; however, considering the nature of the spreads, they are assumed to be stationary in the long run. A small sample size may have caused non-stationarity. The raw data was retained to assess whether the VAR model is stationary later. The data description shows that the average sovereign CDS values in each country were higher during the crisis period than in the post-crisis period. Additionally, the mean values of industrial production growth rate and ECB rate differed significantly between the two periods. During the crisis, each country's industrial production growth rate was negative, but it turned positive in the second model. Moreover, the ECB's policy rates remained positive on average during the crisis but turned negative in the post-crisis period. Furthermore, the average growth rate of aggregate monetary M3 was lower during the crisis than in the post-crisis period.

Figure B2 (in Appendix B) depicts the sovereign CDS spreads of Italy, Ireland, Portugal, and Spain, with Greece's shown in Figure B1 (in Appendix B) due to its significantly higher variance. The vertical blue lines indicate the months in which the ECB changed its overnight deposit interest rate. The range between the two orange vertical lines represents the period during which Greece defaulted and subsequently disappeared from the CDS market. Monetary policy adjustments appeared around the peaks of CDS, as observed in the peaks of Irish CDS in February 2009 and August 2011, and Portugal in January 2012. It is noteworthy that there were two monetary adjustments before Greece re-entered the CDS market. Although CDS spreads may not respond immediately to interest rate changes, they are sensitive to global and local financial and social events. The co-movement of the four countries' CDS spreads rising from March 2010 may have been influenced by Greek public sector wage cuts and worker strikes during that month. Similarly, after the Greek pension reform in July 2010, all countries' spreads increased once again. The spread of Ireland decreased after August 2011 following news of its acceptance of the EU-IMF multibillion-euro package. In April 2012, the Greek government announced its sovereign default, and Spain received a 19 billion euro bailout, leading to a simultaneous decrease in the spreads of all four countries.

3.5 Results

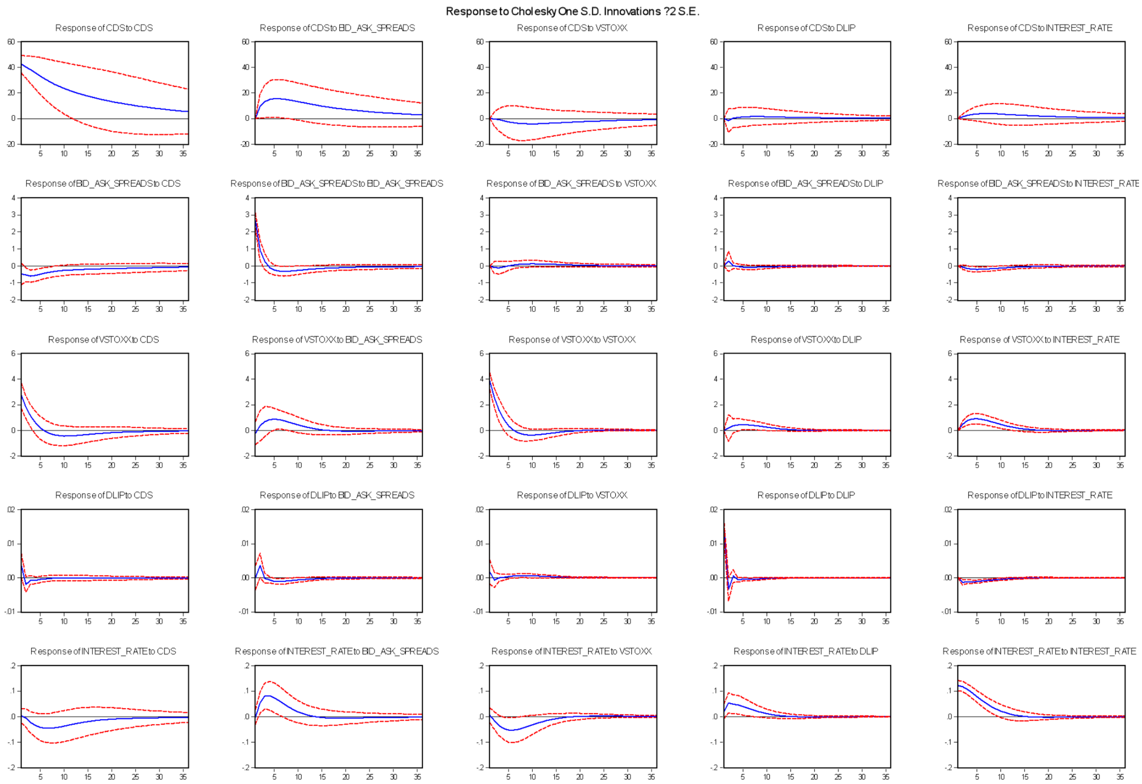
The stability of the VAR models estimated in this study is confirmed by the AR root circle diagram presented in Figure B3 (in Appendix B) of the appendix. The IRF of the VAR model, as shown in Figure 3.1 to 3.10 and Figure B4 to B13 (see in Appendix B), was examined, and the results revealed that the model with ECB interest rates as a variable is more significant compared to that with monetary aggregates. This confirms that other variables respond more quickly to interest rate adjustments than monetary aggregates. Therefore, subsequent analyses, such as variance decomposition[4] (Table 3.1) and Granger causality tests (Table 3.2 to 3.6), are based on the ECB's interest rate model.

This chapter's first research question pertains to how the ECB's monetary policy shocks affect the sovereign CDS market of peripheral countries. In the IRF results, we found that all five countries displayed significant responses in the graphs, with Italy, Ireland, Portugal, and Greece showing significant positive responses

[4]More variance decomposition results present in Appendix B (Table B3 to B7).

in the crisis model. Furthermore, in the post-crisis models, Italy's sovereign CDS showed a significantly negative response to interest rate shocks, while Spain's showed a significantly positive response. Throughout our sample period, ECB rates have consistently fallen. The positive response of four countries during the crisis period aligns with our research hypothesis that negative interest rate shocks result in negative responses of sovereign CDS spreads, which in turn represent sovereign credit risk declining. Notably, in the post-crisis period, Italy and Spain reacted in opposite directions to interest rate shocks, with Spain's positive feedback consistent with our hypothesis. ECB's monetary easing led to a deterioration in Italy's creditworthiness in the sovereign CDS market during the post-crisis period. As seen in previous data description, Italy's sovereign CDS spreads were lower than those of other countries during the crisis period but significantly higher than those of Spain and Ireland during the post-crisis period. This suggests that investors do not expect monetary policy to improve Italy's credit standing more than Spain's. Past literature (Wang and Moore, 2012; Bedendo and Colla, 2015) suggests that sovereign credit, while independent of each country's fundamentals, is susceptible to contagion effects. A deeper perspective can be gained by comparing the industrial production of Italy and Spain, where the Spanish economy has sustained growth, and Italy experienced a trough in 2016. In comparison to Spain, Italy's suboptimal economic performance and unstable political landscape are also crucial determinants influencing the restoration of sovereign credit. Variance decomposition results showed that while most IRF results are significant, the interest rate shock accounts for a relatively small part of the variance in each sovereign CDS, remaining below 1%. Finally, Granger causality tests provided evidence that interest rates affect sovereign CDS in all countries, with interest rates Granger causing sovereign CDS spreads in the traditional way for the Italian and Irish models, in the form of non-linear Granger causality for Portugal, and in both ways Granger causing CDS for the Spanish

Figure 3.1: Impulse Response Functions in ECB Rates Model - Italy, Crisis Period

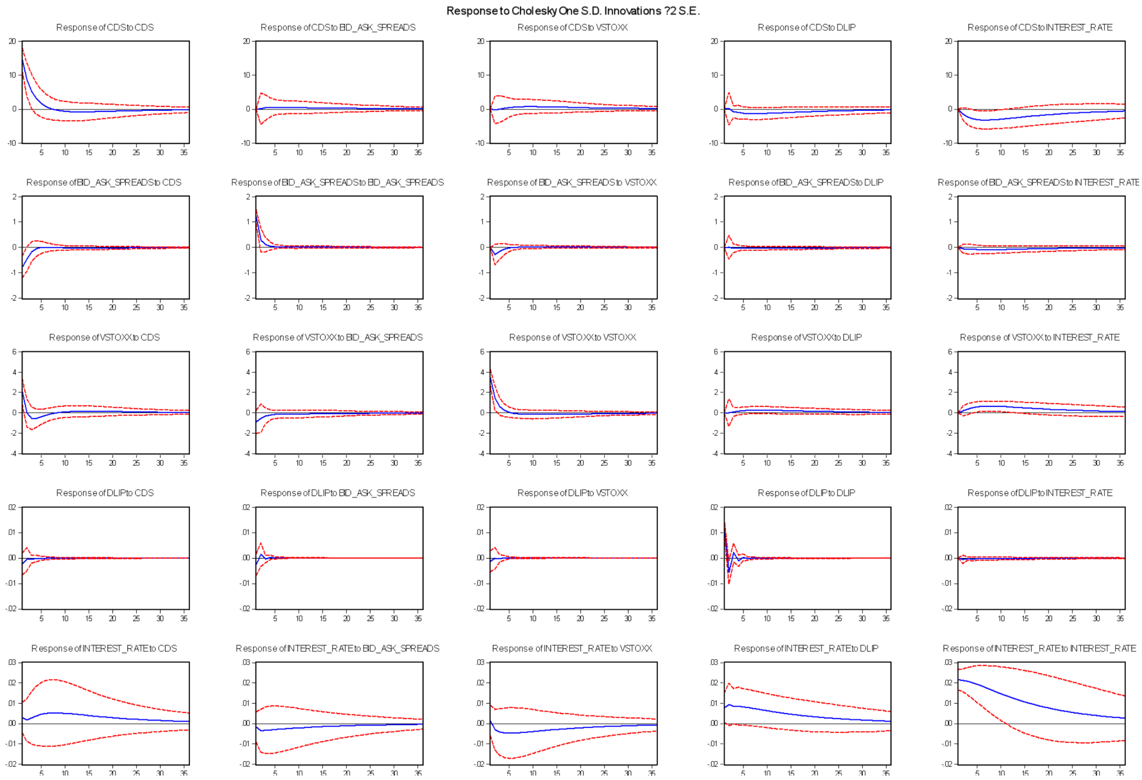


Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

and Greek models.

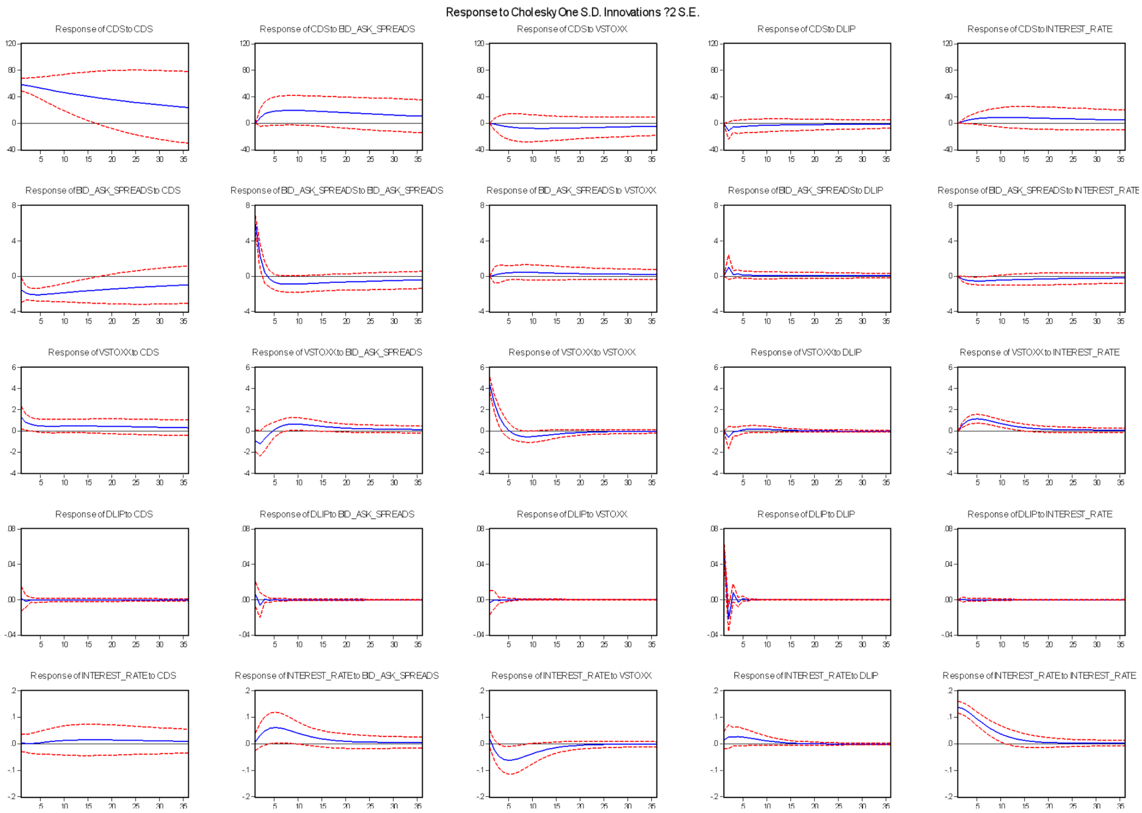
The second research question addressed in this study concerns the impact of variable shocks on sovereign CDS in different periods. The IRF analysis indicates that in the crisis-time models of Italy and Portugal, there is a significant positive feedback between CDS and bid-ask spreads, which contradicts our research hypothesis that better market liquidity leads to a reduction in sovereign creditworthiness. However, this may be attributed to special circumstances during the crisis, where better market liquidity was influenced by external factors such as central bank relief, which investors perceived as indicative of a deteriorating economic and credit environment. As a result, the outcomes of the model are biased and focused on crisis periods. In the crisis model of Portugal, CDS has a

Figure 3.2: Impulse Response Functions in ECB Rates Model - Italy, Post-crisis Period



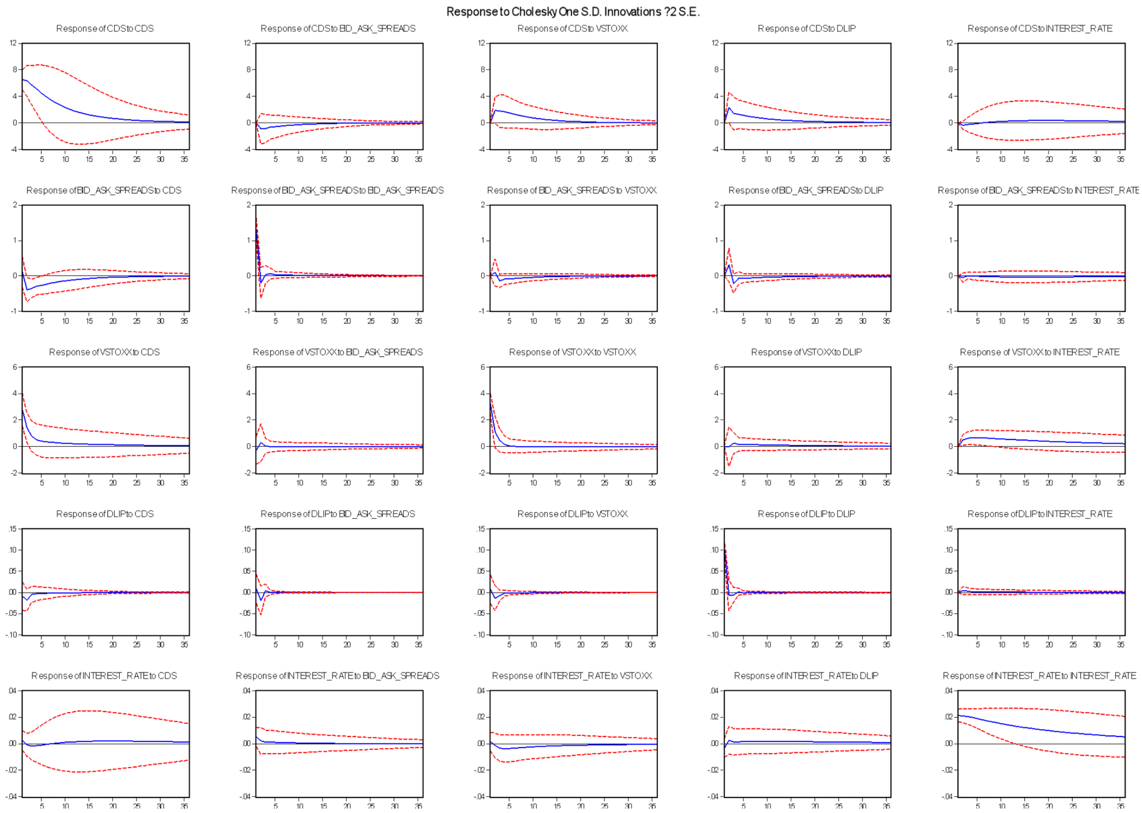
Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure 3.3: Impulse Response Functions in ECB Rates Model - Ireland, Crisis Period



Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure 3.4: Impulse Response Functions in ECB Rates Model - Ireland, Post-crisis Period

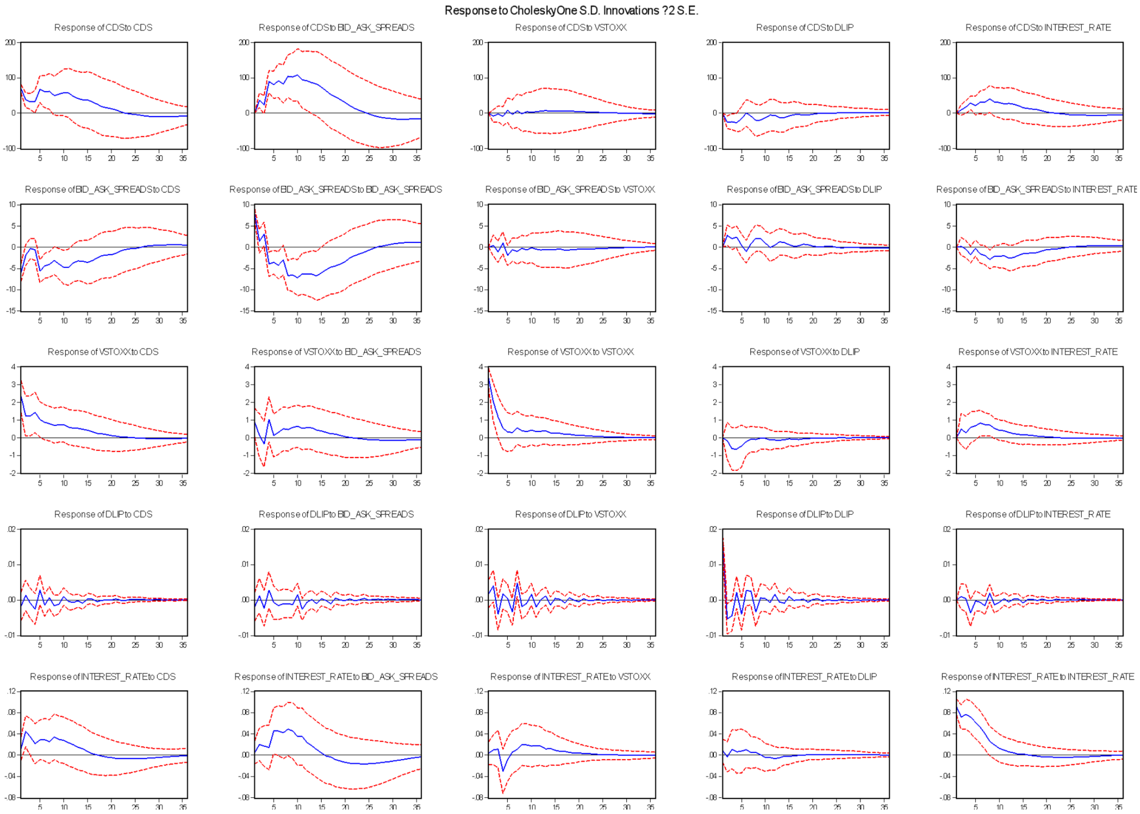


Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

significant negative response on the shock of growth rate of industrial production, which is in line with our hypothesis that economic growth affects sovereign credit during crises. However, in the post-crisis period of Greece, CDS has a significant positive feedback on the shock of growth rate of industrial production, reflecting investors' perception that Greece's growth has no positive impact on sovereign credit. Instead, this is characteristic of the debt crisis, where growth may slow as debts are repaid, leading to better sovereign credit. Further analysis using variance decomposition shows that the impact of bid-ask spreads explained the largest proportion of CDS variance for Portugal and Italy outside of CDS itself during the crisis period. Specifically, the ratio of Portugal's CDS variance affected by liquidity shock was larger than the explanatory power of CDS itself to its variance at the fifth month. In addition, the impact of industrial production growth rate in Portugal during the crisis also significantly explained the variance of CDS in the same period. Meanwhile, the impact of Greece's industrial production growth rate in the post-crisis period also explains a significant proportion of CDS variance. The Granger causality tests indicate that liquidity can Granger cause Italian CDS spreads in both linear and non-linear models, whereas in the Portuguese model, the Granger cause from bid-ask spreads to CDS appears only in the non-linear model.

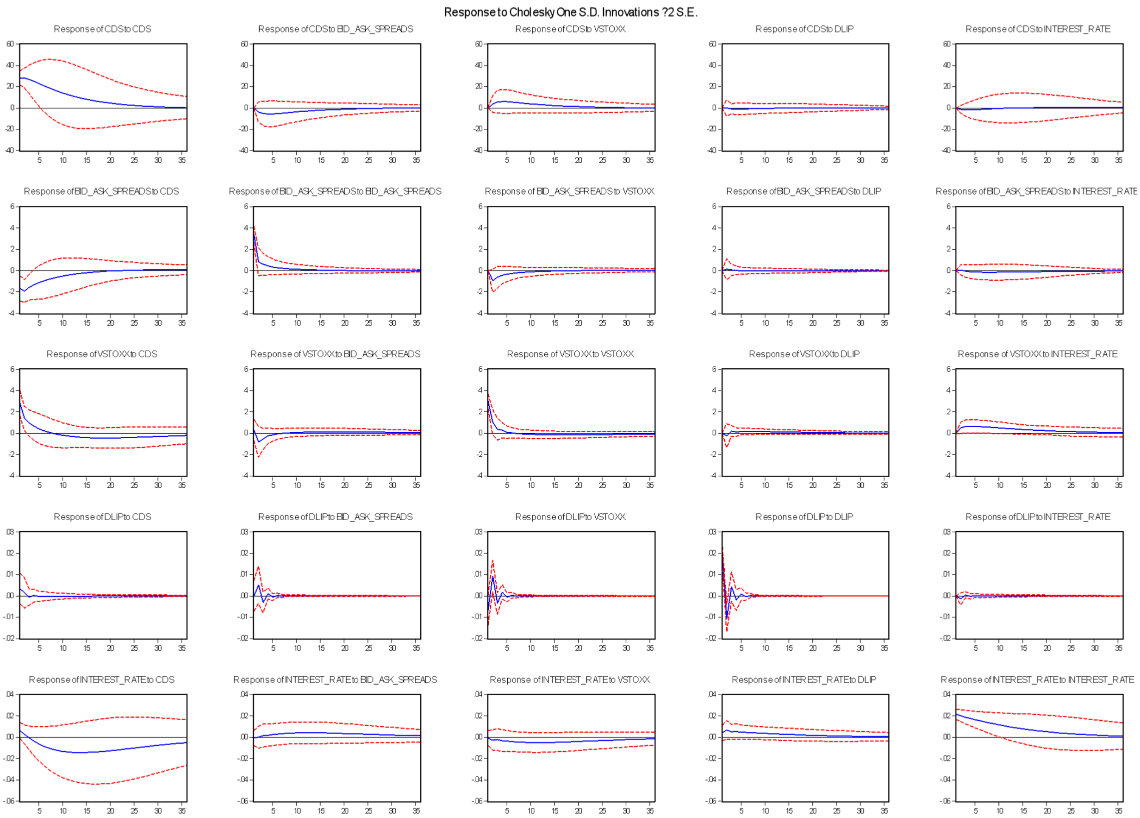
Furthermore, the results of the model presented in this study also reveal several findings. Firstly, bid-ask spreads in all models, except the post-crisis model of Greece, exhibit significant negative responses to the shocks of sovereign CDS in the first five periods. This is intuitively correct that an increase in credit market stability leads to an improvement in liquidity. Moreover, the study finds that sovereign CDS shocks can Granger cause bid-ask spreads in all nonlinear causal models. In the linear model, the causal relationship between Spain and Greece

Figure 3.5: Impulse Response Functions in ECB Rates Model - Portugal, Crisis Period



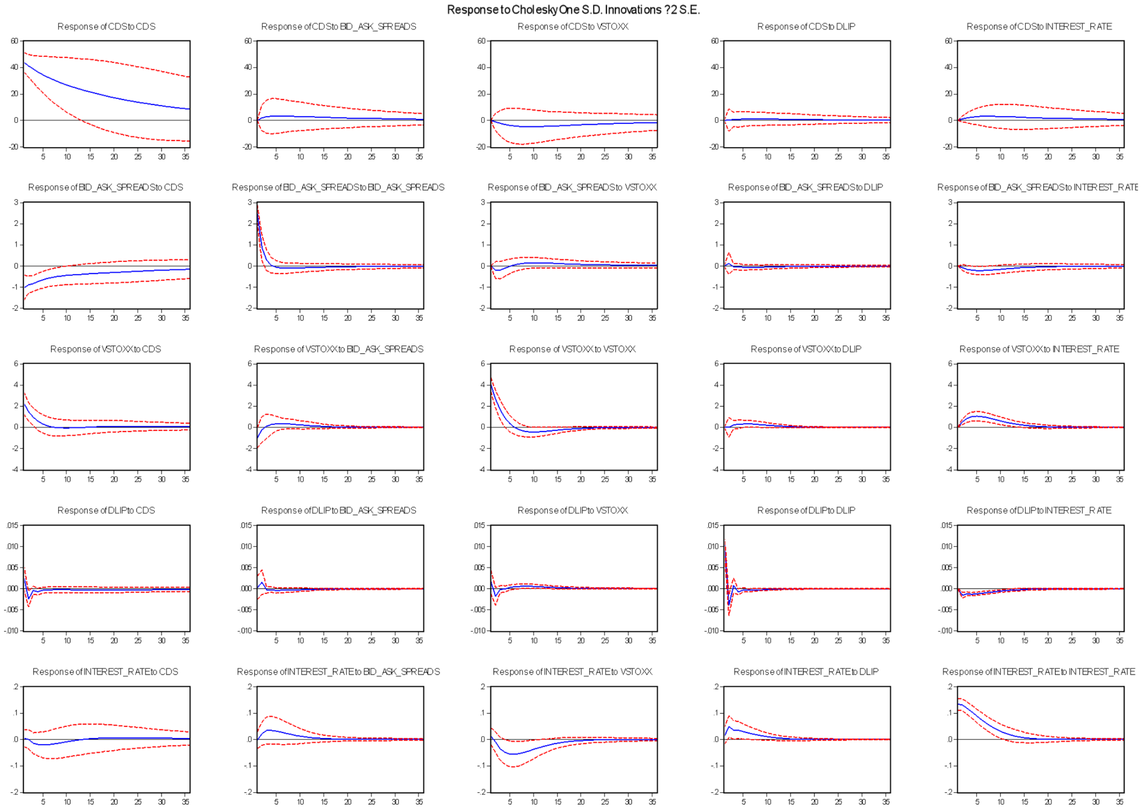
Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure 3.6: Impulse Response Functions in ECB Rates Model - Portugal, Post-crisis Period



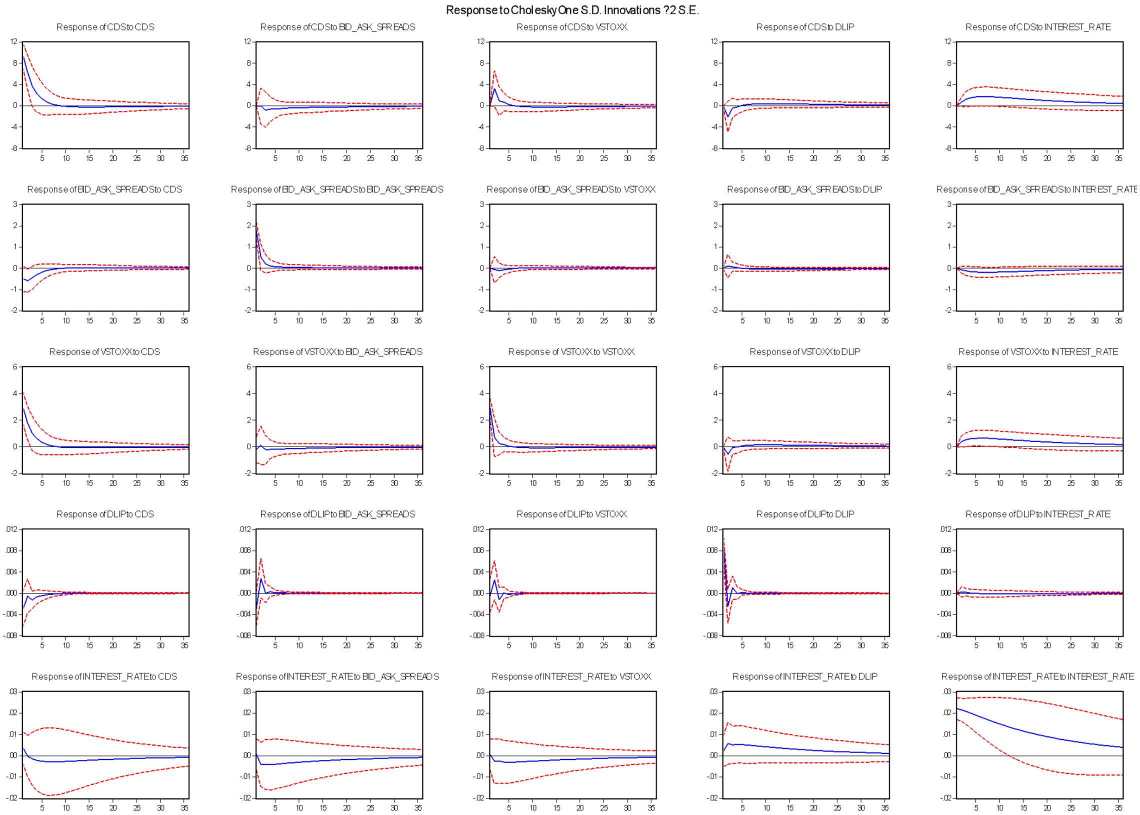
Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure 3.7: Impulse Response Functions in ECB Rates Model - Spain, Crisis Period



Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure 3.8: Impulse Response Functions in ECB Rates Model - Spain, Post-crisis Period

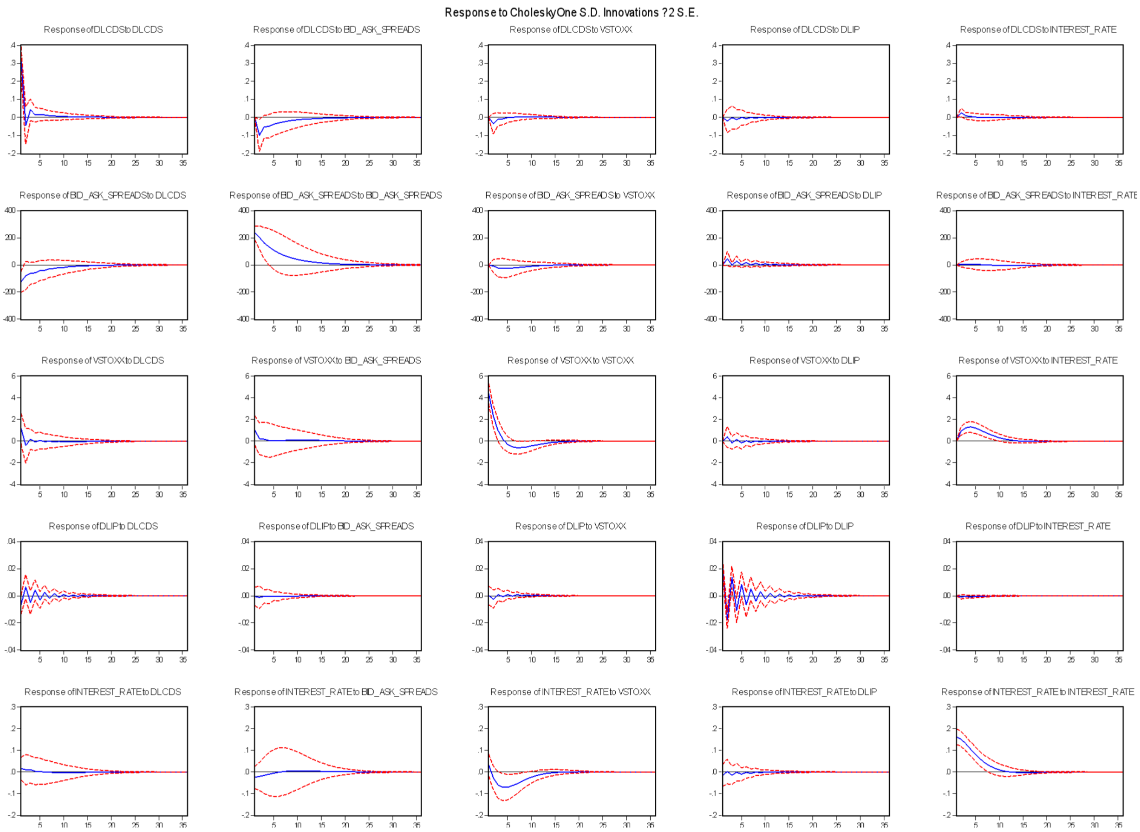


Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

holds. It is also worth noting that the response of bid-ask spreads to CDS shocks is more widespread than the vice versa case, which is only significant in the crisis models of Portugal and Italy. Secondly, in both periods of the model for all countries, excluding Greece, the VSTOXX index demonstrates a significantly positive response to sovereign CDS shocks in the first three months. The response of CDS to shock of VSTOXX, however, is not significant in all models. According to the variance decomposition results of VSTOXX, sovereign CDS plays a significant role in explaining the variance of VSTOXX index in all five national models in the first month. In summary, the fear index of the European stock market is partially influenced by the sovereign credit of peripheral countries of the euro zone (excluding Greece). The results of the study indicate that investors do not consider Greece to have a significant impact on the overall European stock market. This could be due to its unique status in the debt crisis, having experienced sovereign credit default and received the largest amount of subsidies, making its financial impact relatively insignificant compared to other peripheral countries. Thirdly, in the crisis models of Italy and Spain, the growth rate of industrial production shows a significant negative impact on interest rate shocks. This suggests that reducing interest rates during the crisis could have improved the economies of Italy and Spain. Lastly, the VSTOXX index exhibits a significant positive response to the central bank interest rate shock in all models. Combined with the continued monetary easing by the ECB, the study concludes that the monetary policy shocks during the study period led to a significant decrease in stock market jitters in the long-term.

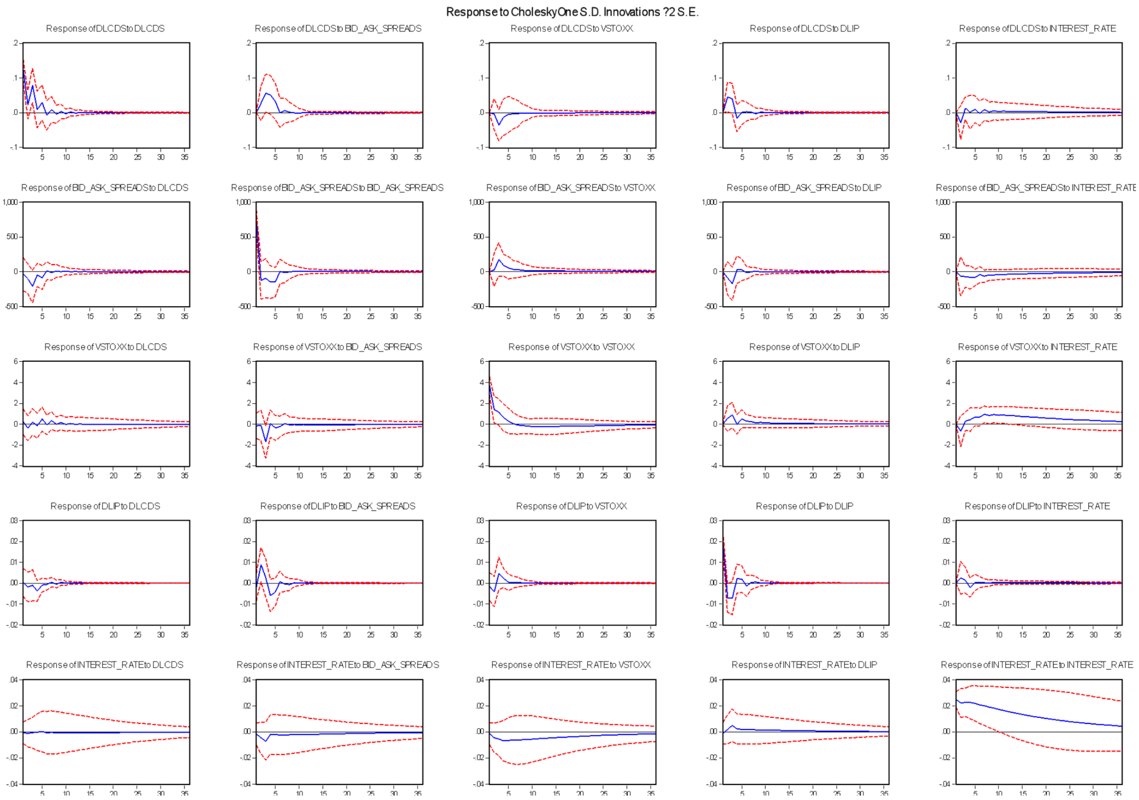
In conclusion, the interest rate reduction policy shocks of the ECB has had a significant impact on the sovereign credit market of peripheral countries, except for Spain during the crisis. In the post-crisis period, only Spain's sovereign credit was positively affected by the impact of interest rate cuts, while Italy's deteri-

Figure 3.9: Impulse Response Functions in ECB Rates Models - Greece, Crisis Period



Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure 3.10: Impulse Response Functions in ECB Rates Models - Greece, Post-crisis Period



Note: Figure 3.1 to 3.10 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 INTEREST_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

orated, potentially due to external factors such as asset transfers. Additionally, we find that besides interest rate shocks, liquidity changes and industrial output growth shocks can also affect the sovereign credit market. The effects of these shocks vary across time and countries, with marginal differences in the determinants of sovereign CDS in different countries at different periods, but there are also commonalities. Finally, we find that in peripheral countries, the impact of the liquidity shock on sovereign credit is less significant than vice versa.

Table 3.1: Variance Decomposition of CDS in ECB Rate Models

Italy - crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	42.69	100.00	0.00	0.00	0.00	0.00
2.00	59.52	97.15	2.71	0.00	0.08	0.05
3.00	72.03	94.51	5.25	0.02	0.06	0.15
4.00	81.87	92.15	7.46	0.07	0.05	0.27
5.00	89.84	90.19	9.21	0.14	0.06	0.39
6.00	96.42	88.59	10.60	0.24	0.08	0.49
7.00	101.91	87.28	11.69	0.35	0.09	0.59
8.00	106.55	86.20	12.56	0.47	0.10	0.66
9.00	110.50	85.33	13.26	0.58	0.11	0.73
10.00	113.89	84.61	13.81	0.68	0.12	0.77

Italy - post-crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	14.64	100.00	0.00	0.00	0.00	0.00
2.00	17.08	99.28	0.00	0.02	0.01	0.68
3.00	18.03	97.47	0.06	0.02	0.21	2.25
4.00	18.53	94.93	0.12	0.03	0.46	4.45
5.00	18.91	91.89	0.19	0.08	0.86	6.98
6.00	19.26	88.74	0.26	0.17	1.27	9.56
7.00	19.60	85.71	0.32	0.28	1.70	12.00
8.00	19.92	82.94	0.37	0.40	2.09	14.20
9.00	20.23	80.47	0.42	0.52	2.45	16.14
10.00	20.52	78.33	0.45	0.64	2.76	17.82

Ireland - crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	58.44	100.00	0.00	0.00	0.00	0.00
2.00	83.01	97.00	0.98	0.03	1.88	0.11
3.00	101.53	95.43	2.67	0.10	1.51	0.28
4.00	116.87	93.85	4.06	0.21	1.40	0.48
5.00	130.06	92.48	5.24	0.34	1.26	0.69
6.00	141.64	91.29	6.20	0.47	1.16	0.88
7.00	151.95	90.26	7.01	0.60	1.08	1.06
8.00	161.24	89.35	7.68	0.74	1.01	1.22
9.00	169.67	88.56	8.26	0.86	0.95	1.37
10.00	177.36	87.87	8.75	0.98	0.90	1.50

Ireland - post-crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	6.49	100.00	0.00	0.00	0.00	0.00
2.00	9.62	89.36	0.90	3.84	5.75	0.15
3.00	11.46	87.90	1.23	5.10	5.60	0.17
4.00	12.74	87.27	1.24	5.81	5.52	0.16
5.00	13.66	86.83	1.25	6.26	5.51	0.14
6.00	14.33	86.59	1.26	6.52	5.50	0.13
7.00	14.82	86.43	1.26	6.69	5.50	0.12
8.00	15.19	86.32	1.26	6.79	5.51	0.12
9.00	15.46	86.25	1.26	6.85	5.51	0.13
10.00	15.67	86.18	1.26	6.89	5.52	0.15

Portugal - crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	92.48	100.00	0.00	0.00	0.00	0.00
2.00	122.87	84.28	11.78	0.07	3.87	0.01
3.00	148.46	68.74	27.95	0.08	3.17	0.05
4.00	172.77	55.52	41.56	0.14	2.68	0.10
5.00	195.23	45.82	51.57	0.23	2.23	0.16
6.00	215.51	38.86	58.70	0.34	1.91	0.20
7.00	233.57	33.84	63.81	0.45	1.66	0.23
8.00	249.51	30.14	67.56	0.56	1.49	0.25
9.00	263.55	27.35	70.37	0.67	1.35	0.26
10.00	275.91	25.20	72.52	0.76	1.25	0.27

Portugal - post-crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	28.21	100.00	0.00	0.00	0.00	0.00
2.00	40.23	98.13	0.92	0.84	0.00	0.11
3.00	49.01	96.11	1.71	1.92	0.04	0.22
4.00	55.64	94.64	2.38	2.63	0.06	0.28
5.00	60.77	93.61	2.84	3.16	0.08	0.31
6.00	64.76	92.90	3.17	3.52	0.09	0.32
7.00	67.90	92.40	3.40	3.78	0.09	0.33
8.00	70.37	92.05	3.57	3.97	0.10	0.32
9.00	72.34	91.80	3.69	4.10	0.10	0.31
10.00	73.90	91.61	3.78	4.20	0.10	0.31

Spain - crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	44.04	100.00	0.00	0.00	0.00	0.00
2.00	60.44	99.82	0.11	0.03	0.00	0.04
3.00	71.99	99.54	0.23	0.11	0.01	0.10
4.00	80.96	99.23	0.33	0.23	0.02	0.19
5.00	88.26	98.91	0.42	0.37	0.03	0.27
6.00	94.37	98.60	0.49	0.52	0.04	0.34
7.00	99.60	98.31	0.55	0.67	0.05	0.41
8.00	104.12	98.05	0.60	0.81	0.06	0.47
9.00	108.07	97.82	0.64	0.95	0.07	0.52
10.00	111.56	97.62	0.67	1.07	0.08	0.57

Spain - post-crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	9.53	100.00	0.00	0.00	0.00	0.00
2.00	12.09	89.72	0.00	7.08	2.85	0.35
3.00	12.76	88.84	0.38	6.84	2.65	1.29
4.00	13.09	87.49	0.59	6.78	2.55	2.59
5.00	13.28	86.01	0.78	6.62	2.48	4.12
6.00	13.42	84.46	0.90	6.48	2.46	5.70
7.00	13.55	82.92	1.00	6.36	2.47	7.25
8.00	13.68	81.46	1.08	6.25	2.50	8.70
9.00	13.79	80.11	1.14	6.17	2.54	10.03
10.00	13.90	78.89	1.19	6.10	2.59	11.23

Greece - crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	0.32	100.00	0.00	0.00	0.00	0.00
2.00	0.34	89.68	8.37	1.02	0.34	0.58
3.00	0.35	87.69	10.29	1.08	0.33	0.61
4.00	0.36	85.88	11.97	1.10	0.43	0.62
5.00	0.36	84.95	12.91	1.09	0.42	0.62
6.00	0.36	84.32	13.53	1.08	0.46	0.61
7.00	0.36	83.92	13.93	1.08	0.45	0.61
8.00	0.36	83.65	14.19	1.08	0.47	0.60
9.00	0.36	83.47	14.37	1.09	0.47	0.60
10.00	0.36	83.35	14.48	1.09	0.47	0.60

Greece - post-crisis

Variance Decomposition of CDS:

Period	S.E.	CDS	Bid-ask Spreads	VSTOXX	Industrial Production	Interest Rate
1.00	0.12	100.00	0.00	0.00	0.00	0.00
2.00	0.14	81.30	3.91	0.08	10.65	4.06
3.00	0.18	69.13	12.24	4.09	11.50	3.03
4.00	0.19	63.12	18.70	4.20	11.22	2.76
5.00	0.19	61.94	20.55	4.03	10.60	2.87
6.00	0.19	61.95	20.51	4.05	10.60	2.88
7.00	0.19	61.83	20.50	4.05	10.55	3.07
8.00	0.19	61.83	20.48	4.05	10.56	3.08
9.00	0.19	61.78	20.46	4.05	10.56	3.16
10.00	0.19	61.77	20.45	4.05	10.56	3.18

Note: This table shows the variance decomposition of five countries'(Italy, Ireland, Portugal, Spain and Greece) sovereign credit default swap spreads with two sub-periods - the crisis period (July 2008 to September 2014) and the post-crisis period (October 2014 to December 2017). DLIP denotes the log-difference of industrial production of this country. The results are rounded to two decimal places.
Source: Eviews8.

Table 3.2: Linear and Non-Linear Granger Causality Tests of Whole Sample Models - Italy

Linear Granger Causality Test				Non-linear Granger Causality Test			
Dependent variable: CDS							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
VSTOXX	2.26	1.00	0.13	VSTOXX	0.00	-49.25	1.00
Bid-ask Spreads	**2.83**	**1.00**	**0.09**	**Bid-ask Spreads**	**0.31**	**38.66**	**0.00**
Interest Rate	8.19	1.00	0.00	Interest Rate	0.00	-1.86	1.00
Industrial Production	0.59	1.00	0.44	Industrial Production	0.04	4.66	0.03
All	11.53	4.00	0.02				
Dependent variable: VSTOXX							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	0.02	1.00	0.88	CDS	0.00	-5.53	1.00
Bid-ask Spreads	0.35	1.00	0.56	Bid-ask Spreads	0.29	35.54	0.00
Interest Rate	**47.35**	**1.00**	**0.00**	**Interest Rate**	**0.02**	**1.79**	**0.18**
Industrial Production	0.76	1.00	0.38	Industrial Production	0.00	-16.19	1.00
All	50.35	4.00	0.00				
Dependent variable: Bid-ask Spreads							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	2.57	1.00	0.11	CDS	0.69	105.88	0.00
VSTOXX	0.17	1.00	0.68	VSTOXX	0.00	-28.60	1.00
Interest Rate	0.12	1.00	0.73	Interest Rate	0.04	4.33	0.04
Industrial Production	0.08	1.00	0.78	Industrial Production	0.00	-33.25	1.00
All	5.01	4.00	0.29				
Dependent variable: Interest Rate							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	1.65	1.00	0.20	CDS	0.00	-11.90	1.00
VSTOXX	17.39	1.00	0.00	VSTOXX	0.00	-31.99	1.00
Bid-ask Spreads	3.16	1.00	0.08	Bid-ask Spreads	0.00	-14.41	1.00
Industrial Production	1.88	1.00	0.17	Industrial Production	0.00	-14.06	1.00
All	18.33	4.00	0.00				
Dependent variable: Industrial Production							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	0.21	1.00	0.64	CDS	0.00	-34.91	1.00
VSTOXX	0.00	1.00	0.97	VSTOXX	0.13	15.26	0.00
Bid-ask Spreads	0.44	1.00	0.51	Bid-ask Spreads	0.00	-3.63	1.00
Interest Rate	0.00	1.00	0.96	Interest Rate	0.00	-23.74	1.00
All	0.77	4.00	0.94				

ds *Note:* Left columns present linear Granger causality tests outputs based on the vector autoregressive models, and right columns refer to non-linear results based on the vector autoregressive neural network models. Bold and underline results are significant in both linear and non-linear tests. The results are rounded to two decimal places.
Source: Eviews8 and RStudio.

Table 3.3: Linear and Non-Linear Granger Causality Tests of Whole Sample Models - Ireland

Linear Granger Causality Test / **Non-linear Granger Causality Test**

Dependent variable: CDS

Excluded	Chi-sq	df	Prob.	Excluded	Granger causality index	F-statistics	P-value
VSTOXX	1.50	1.00	0.22	VSTOXX	0.00	-22.23	1.00
Bid-ask Spreads	0.09	1.00	0.77	Bid-ask Spreads	0.00	-11.98	1.00
Interest Rate	5.65	1.00	0.02	Interest Rate	0.00	-9.66	1.00
industrial Production	1.09	1.00	0.30	industrial Production	0.00	-6.55	1.00
All	7.36	4.00	0.12				

Dependent variable: VSTOXX

Excluded	Chi-sq	df	Prob.	Excluded	Granger causality index	F-statistics	P-value
DCDS	0.17	1.00	0.68	cds	0.31	39.52	0.00
Bid-ask Spreads	0.18	1.00	0.68	Bid-ask Spreads	0.53	74.36	0.00
Interest Rate	**40.64**	**1.00**	**0.00**	**Interest Rate**	**0.07**	**8.03**	**0.01**
industrial Production	0.06	1.00	0.80	industrial Production	0.23	27.09	0.00
All	42.84	4.00	0.00				

Dependent variable: Bid-ask Spreads

Excluded	Chi-sq	df	Prob.	Excluded	Granger causality index	F-statistics	P-value
DCDS	0.07	1.00	0.80	cds	0.18	21.64	0.00
VSTOXX	0.66	1.00	0.42	VSTOXX	0.00	-64.27	1.00
Interest Rate	0.22	1.00	0.64	Interest Rate	0.00	-35.97	1.00
industrial Production	0.13	1.00	0.72	industrial Production	0.00	-63.27	1.00
All	0.88	4.00	0.93				

Dependent variable: Interest Rate

Excluded	Chi-sq	df	Prob.	Excluded	Granger causality index	F-statistics	P-value
DCDS	0.54	1.00	0.46	cds	0.00	-21.03	1.00
VSTOXX	**9.51**	**1.00**	**0.00**	**VSTOXX**	**0.32**	**40.56**	**0.00**
Bid-ask Spreads	9.17	1.00	0.00	Bid-ask Spreads	0.00	-24.41	1.00
industrial Production	0.31	1.00	0.58	industrial Production	0.00	-6.31	1.00
All	21.83	4.00	0.00				

Dependent variable: Industrial Production

Excluded	Chi-sq	df	Prob.	Excluded	Granger causality index	F-statistics	P-value
DCDS	0.03	1.00	0.87	cds	0.00	-33.17	1.00
VSTOXX	0.38	1.00	0.54	VSTOXX	0.13	14.94	0.00
Bid-ask Spreads	0.01	1.00	0.91	Bid-ask Spreads	0.15	16.99	0.00
Interest Rate	0.01	1.00	0.92	Interest Rate	0.00	-4.62	1.00
All	0.54	4.00	0.97				

Note: Left columns present linear Granger causality tests outputs based on the vector autoregressive models, and right columns refer to non-linear results based on the vector autoregressive neural network models. Bold and underline results are significant in both linear and non-linear tests. The results are rounded to two decimal places.
Source: Eviews8 and RStudio.

Table 3.4: Linear and Non-Linear Granger Causality Tests of Whole Sample Models - Portugal

Linear Granger Causality Test				**Non-linear Granger Causality Test**			
Dependent variable: CDS							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
VSTOXX	0.24	1.00	0.62	VSTOXX	0.00	-1.92	1.00
Bid-ask Spreads	0.13	1.00	0.72	Bid-ask Spreads	0.08	9.34	0.00
Interest Rate	0.81	1.00	0.37	Interest Rate	0.13	15.09	0.00
Industrial Production	3.00	1.00	0.08	Industrial Production	0.00	-15.61	1.00
All	4.58	4.00	0.33				
Dependent variable: VSTOXX							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	1.50	1.00	0.22	CDS	0.00	-28.23	1.00
Bid-ask Spreads	0.08	1.00	0.77	Bid-ask Spreads	0.63	93.89	0.00
Interest Rate	**47.14**	**1.00**	**0.00**	**Interest Rate**	**0.54**	**75.82**	**0.00**
Industrial Production	0.00	1.00	0.99	Industrial Production	0.08	9.14	0.00
All	51.22	4.00	0.00				
Dependent variable: Bid-ask Spreads							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	0.35	1.00	0.55	CDS	0.76	120.67	0.00
VSTOXX	0.50	1.00	0.48	VSTOXX	0.02	2.20	0.14
Interest Rate	0.00	1.00	0.96	Interest Rate	0.00	-1.74	1.00
Industrial Production	0.45	1.00	0.50	Industrial Production	0.17	19.82	0.00
All	2.16	4.00	0.71				
Dependent variable: Interest Rate							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	5.79	1.00	0.02	CDS	0.00	-16.41	1.00
VSTOXX	17.75	1.00	0.00	VSTOXX	0.00	-20.93	1.00
Bid-ask Spreads	**2.71**	**1.00**	**0.10**	**Bid-ask Spreads**	**0.34**	**43.75**	**0.00**
Industrial Production	1.02	1.00	0.31	Industrial Production	0.12	13.21	0.00
All	23.82	4.00	0.00				
Dependent variable: Industrial Production							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	0.30	1.00	0.58	CDS	0.25	29.76	0.00
VSTOXX	0.21	1.00	0.65	VSTOXX	0.24	29.15	0.00
Bid-ask Spreads	0.31	1.00	0.58	Bid-ask Spreads	0.00	-28.29	1.00
Interest Rate	6.53	1.00	0.01	Interest Rate	0.00	-5.06	1.00
All	9.73	4.00	0.05				

Note: Left columns present linear Granger causality tests outputs based on the vector autoregressive models, and right columns refer to non-linear results based on the vector autoregressive neural network models. Bold and underline results are significant in both linear and non-linear tests. The results are rounded to two decimal places.
Source: Eviews8 and RStudio.

Table 3.5: Linear and Non-Linear Granger Causality Tests of Whole Sample Models - Spain

Linear Granger Causality Test				**Non-linear Granger Causality Test**			
Dependent variable: CDS							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
VSTOXX	1.48	1.00	0.22	VSTOXX	0.39	51.77	0.00
Bid-ask Spreads	2.31	1.00	0.13	Bid-ask Spreads	0.03	3.06	0.08
Interest Rate	**4.39**	**1.00**	**0.04**	**Interest Rate**	**0.25**	**30.17**	**0.00**
Industrial Production	0.25	1.00	0.62	Industrial Production	0.46	62.32	0.00
All	7.02	4.00	0.13				
Dependent variable: VSTOXX							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
DCDS	0.20	1.00	0.65	CDS	0.04	4.69	0.03
Bid-ask Spreads	0.49	1.00	0.49	Bid-ask Spreads	0.00	-32.92	1.00
Interest Rate	**48.50**	**1.00**	**0.00**	**Interest Rate**	**0.51**	**72.00**	**0.00**
Industrial Production	1.90	1.00	0.17	Industrial Production	0.00	-9.72	1.00
All	52.41	4.00	0.00				
Dependent variable: Bid-ask Spreads							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
DCDS	**5.12**	**1.00**	**0.02**	**CDS**	**0.31**	**38.28**	**0.00**
VSTOXX	0.01	1.00	0.93	VSTOXX	0.43	57.31	0.00
Interest Rate	0.01	1.00	0.93	Interest Rate	0.00	-38.65	1.00
Industrial Production	0.51	1.00	0.47	Industrial Production	0.46	62.41	0.00
All	5.87	4.00	0.21				
Dependent variable: Interest Rate							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
DCDS	0.95	1.00	0.33	CDS	0.37	48.21	0.00
VSTOXX	13.85	1.00	0.00	VSTOXX	0.00	-11.63	1.00
Bid-ask Spreads	0.71	1.00	0.40	Bid-ask Spreads	0.00	-34.71	1.00
Industrial Production	**8.10**	**1.00**	**0.00**	**Industrial Production**	**0.15**	**16.97**	**0.00**
All	24.54	4.00	0.00				
Dependent variable: Industrial Production							
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
DCDS	0.03	1.00	0.87	CDS	0.00	-4.08	1.00
VSTOXX	2.66	1.00	0.10	VSTOXX	0.30	37.49	0.00
Bid-ask Spreads	0.88	1.00	0.35	Bid-ask Spreads	0.51	71.33	0.00
Interest Rate	23.46	1.00	0.00	Interest Rate	0.00	-20.58	1.00
All	55.29	4.00	0.00				

Note: Left columns present linear Granger causality tests outputs based on the vector autoregressive models, and right columns refer to non-linear results based on the vector autoregressive neural network models. Bold and underline results are significant in both linear and non-linear tests. The results are rounded to two decimal places.
Source: Eviews8 and RStudio.

Table 3.6: Linear and Non-Linear Granger Causality Tests of Whole Sample Models - Greece

Linear Granger Causality Test				**Non-linear Granger Causality Test**			
				Dependent variable: CDS			
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
VSTOXX	6.17	2.00	0.05	VSTOXX	0.00	-0.56	1.00
Bid-ask Spreads	21.29	2.00	0.00	Bid-ask Spreads	0.00	-7.67	1.00
Interest Rate	**9.41**	**2.00**	**0.01**	**Interest Rate**	**0.07**	**7.68**	**0.01**
Industrial Production	1.78	2.00	0.41	Industrial Production	0.00	-2.21	1.00
All	43.86	8.00	0.00				
				Dependent variable: VSTOXX			
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	2.80	2.00	0.25	CDS	0.68	103.62	0.00
Bid-ask Spreads	0.57	2.00	0.75	Bid-ask Spreads	0.12	13.56	0.00
Interest Rate	**20.90**	**2.00**	**0.00**	**Interest Rate**	**0.05**	**5.46**	**0.02**
Industrial Production	0.67	2.00	0.71	Industrial Production	0.00	-52.18	1.00
All	29.60	8.00	0.00				
				Dependent variable: Bid-ask Spreads			
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	**7.43**	**2.00**	**0.02**	**CDS**	**0.37**	**47.73**	**0.00**
VSTOXX	2.85	2.00	0.24	VSTOXX	0.21	24.69	0.00
Interest Rate	2.21	2.00	0.33	Interest Rate	0.19	22.99	0.00
Industrial Production	**14.18**	**2.00**	**0.00**	**Industrial Production**	**0.79**	**129.06**	**0.00**
All	20.14	8.00	0.01				
				Dependent variable: Interest Rate			
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	0.69	2.00	0.71	CDS	0.00	-23.11	1.00
VSTOXX	**11.03**	**2.00**	**0.00**	**VSTOXX**	**0.32**	**40.08**	**0.00**
Bid-ask Spreads	5.47	2.00	0.06	Bid-ask Spreads	0.00	-6.12	1.00
Industrial Production	6.06	2.00	0.05	Industrial Production	0.00	-34.12	1.00
All	17.39	8.00	0.03				
				Dependent variable: Industrial Production			
Excluded	Chi-sq	df	Prob.		Granger causality index	F-statistics	P-value
CDS	5.96	2.00	0.05	CDS	0.00	-25.31	1.00
VSTOXX	0.76	2.00	0.69	VSTOXX	0.03	2.76	0.10
Bid-ask Spreads	0.16	2.00	0.92	Bid-ask Spreads	0.03	2.90	0.09
Interest Rate	0.70	2.00	0.70	Interest Rate	0.00	-17.75	1.00
All	9.77	8.00	0.28				

Note: Left columns present linear Granger causality tests outputs based on the vector autoregressive models, and right columns refer to non-linear results based on the vector autoregressive neural network models. Bold and underline results are significant in both linear and non-linear tests. The results are rounded to two decimal places.
Source: Eviews8 and RStudio.

3.6 Conclusion

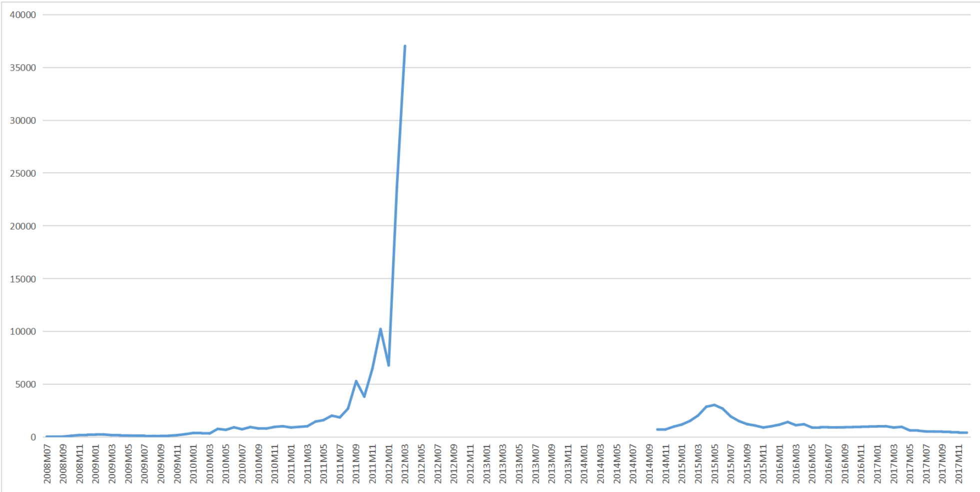
In this chapter, we employed the VAR model and nonlinear Granger causality analysis to examine the effects of the ECB's loose monetary policy on sovereign credit default swap spreads in five euro area countries, while controlling for market liquidity, risk perception, and economic fundamentals. Our findings suggested that although sovereign CDS are not a direct target of the ECB's monetary policy, investigating the determinants of interest rate differentials could provide guidance for investors and illuminate differences across eurozone countries. Moreover, understanding the effects of sovereign CDS on unconventional monetary policies and other factors could have implications for both investors and policy-making authorities.

Notably, our analysis incorporated a unique combination of linear and non-linear Granger causality tests based on the VARNN model, which represented the first application of this methodology to the CDS market. In contrast to prior literature, we used the European stock market index instead of the commonly used American stock market index in our variable selection for systemic risk in the model, and included macroeconomic variable shocks. Our results indicated that shocks to the European stock market do not significantly affect the sovereign credit of the five peripheral European countries, while the sovereign credit of these countries significantly affects the European stock market. Additionally, our study demonstrated that the ECB's interest rate reduction policy effectively reduced the sovereign credit risk of the five peripheral countries during the crisis period. However, in the post-crisis period, this effect was not universal and was only observed in the case of Spain.

We acknowledged that the use of monthly data in financial time series analysis might limit the availability of information, as CDS spreads could change rapidly in response to exogenous shocks. Furthermore, macroeconomic data were primarily reported on a monthly or quarterly basis, which could pose limitations for models that incorporate these variables when working with small sample sizes. Finally, we noted that the sovereign credit markets of different peripheral countries might react differently to the shock of interest rate cuts in the post-crisis period, indicating the need for further research on external variables that could explain this phenomenon.

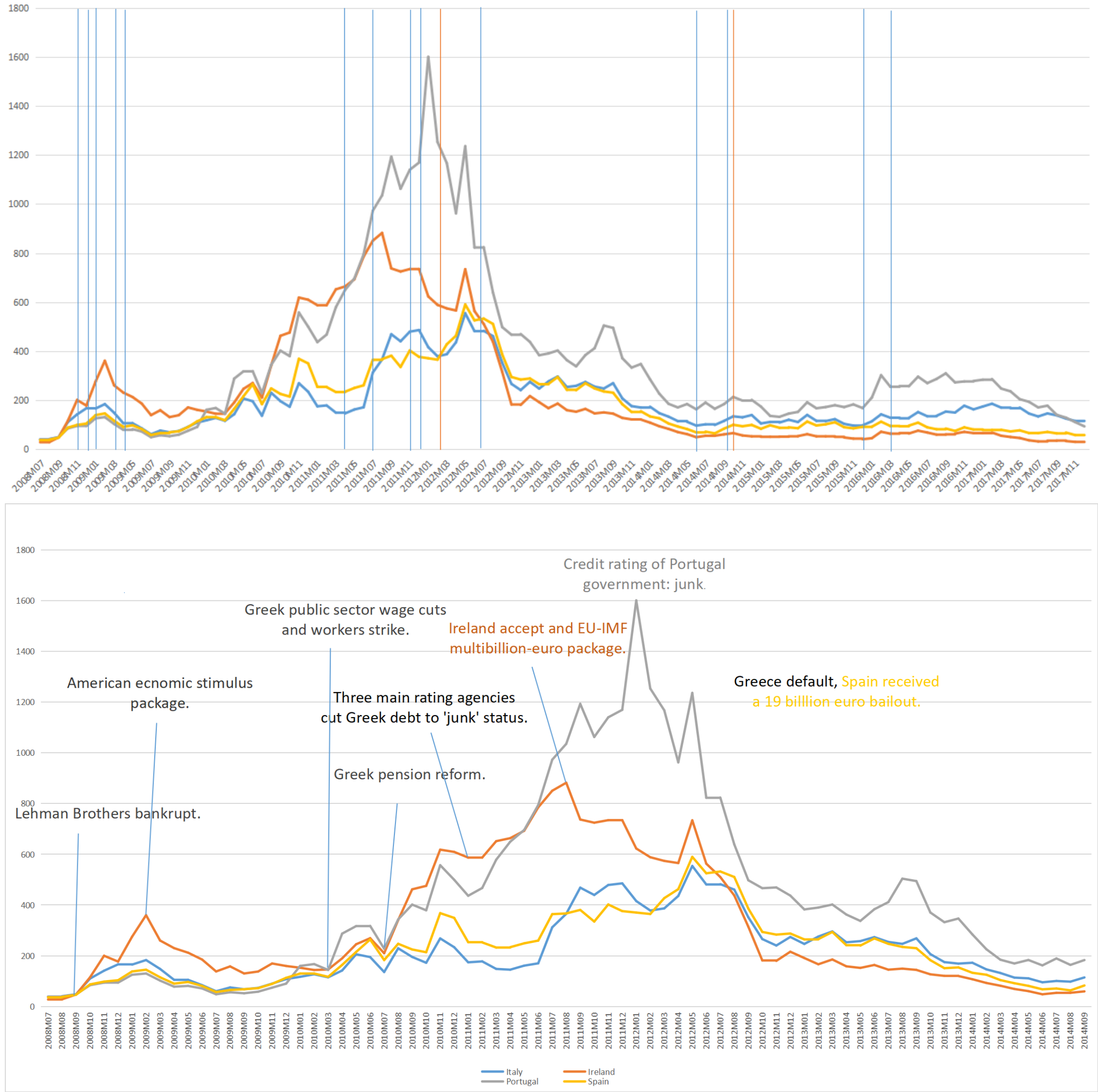
3.7 Appendix B

Figure B1: Greek Credit Default Swaps Spreads



Note: This figure presents an overall trend of Greece 5-year maturity sovereign CDS spreads from July 2008 to December 2017. The missing data from April 2012 to September 2014 due to the credit event triggered and Greek government defaulted in CDS market. Y-axis indicates the basis points of Greek sovereign CDS spread.
Source: Thomson Reuters Datastream.

Figure B2: Sovereign Credit Default Swaps Spreads of Italy, Ireland, Portugal and Spain



Note: In the first chart, the vertical blue lines indicate that the European central bank changed the overnight deposit interest rate that month. The range between two orange vertical lines specifies the Greek default and disappearance from the CDS market. The second chart lists key events with turn points during the crisis.Y-axis indicates the basis points of sovereign CDS spread.

Source: Thomson Reuters Datastream.

Table B1: Data Description - Crisis Models

Italy	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	216.01	-6.79	0.00	26.65	0.43	0.00
Medium	174.04	-5.60	0.00	23.93	0.25	0.00
Maximum	553.89	-1.02	0.04	60.68	3.25	0.02
Minimum	38.75	-16.70	-0.04	14.65	-0.20	-0.02
Std. Dev.	128.54	3.43	0.02	9.16	0.80	0.00
Skewness	0.89	-1.04	-0.23	1.29	2.76	-0.65
Kurtosis	2.85	3.49	2.76	4.77	9.68	10.02
Jarque-Bera	9.94	14.15	0.87	30.62	234.67	157.31
Observations	75.0	75.0	75.0	75.0	75.0	74.0
ADF test in level (t-statistic)	-0.68	-4.84***	-8.15***	-4.18***	-4.63***	-6.94***

Ireland	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	312.49	-14.90	0.00	26.65	0.43	0.00
Medium	189.65	-10.00	0.00	23.93	0.25	0.00
Maximum	882.08	-2.00	0.15	60.68	3.25	0.02
Minimum	27.50	-62.38	-0.27	14.65	-0.20	-0.02
Std. Dev.	244.40	11.39	0.06	9.16	0.80	0.00
Skewness	0.80	-1.94	-1.09	1.29	2.76	-0.65
Kurtosis	2.20	7.48	7.34	4.77	9.68	10.02
Jarque-Bera	9.96	109.55	73.78	30.62	234.67	157.31
Observations	75	75	75	75	75	74
ADF test in level (t-statistic)	-0.64	-2.93**	-9.49***	-4.18***	-4.63***	-6.94***

Portugal	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	429.28	-22.46	0.00	26.65	0.43	0.00
Medium	346.68	-13.31	0.00	23.93	0.25	0.00
Maximum	1,600.98	-2.00	0.04	60.68	3.25	0.02
Minimum	38.50	-133.13	-0.05	14.65	-0.20	-0.02
Std. Dev.	368.25	25.24	0.02	9.16	0.80	0.00
Skewness	1.17	-2.15	0.03	1.29	2.76	-0.65
Kurtosis	3.61	7.86	2.44	4.77	9.68	10.02
Jarque-Bera	18.30	131.65	0.98	30.62	234.67	157.31
Observations	75	75	75	75	75	74
ADF test in level (t-statistic)	-1.13	-1.25	-7.58***	-4.18***	-4.63***	-6.94***

Spain	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	219.62	-6.63	0.00	26.65	0.43	0.00
Medium	224.67	-5.16	0.00	23.93	0.25	0.00
Maximum	589.85	-2.00	0.03	60.68	3.25	0.02
Minimum	36.00	-20.00	-0.06	14.65	-0.20	-0.02
Std. Dev.	134.38	3.66	0.02	9.16	0.80	0.00
Skewness	0.69	-1.25	-0.84	1.29	2.76	-0.65
Kurtosis	2.79	4.77	4.33	4.77	9.68	10.02
Jarque-Bera	6.13	29.29	14.28	30.62	234.67	157.31
Observations	75	75	75	75	75	74
ADF test in level (t-statistic)	-0.69	-4.15***	-9.00***	-4.18***	-4.63***	-6.94***

Greece	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	2,615.98	-262.67	-0.01	26.65	0.43	0.00
Medium	751.46	-45.01	-0.01	23.93	0.25	0.00
Maximum	37,030.49	-2.00	0.07	60.68	3.25	0.02
Minimum	49.75	-2,071.00	-0.09	14.65	-0.20	-0.02
Std. Dev.	6,548.86	493.92	0.03	9.16	0.80	0.00
Skewness	4.11	-2.33	-0.07	1.29	2.76	-0.65
Kurtosis	20.24	7.38	3.18	4.77	9.68	10.02
Jarque-Bera	684.05	127.94	0.16	30.62	234.67	157.31
Observations	45	75	74	75	75	74
ADF test in level (t-statistic)	-1.32	-2.07**	-17.58***	-4.18***	-4.63***	-6.94***

Note: This figure presents the monthly data decription in the crisis period(July 2008 to September 2014). Rows of ADF test in level indicate whether series are stationary or not. Stars follow the t-statistics show the significance level: * for 90%, ** for 95%, *** for 99%. The results are rounded to two decimal places.
Source: Thomson Reuters Datastream, and author's calculation.

Table B2: Data Description - Post-crisis Models

Italy	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	133.42	-7.52	0.00	20.76	-0.32	0.00
Medium	132.57	-7.26	0.01	20.32	-0.40	0.00
Maximum	184.67	-4.86	0.04	32.31	-0.20	0.01
Minimum	95.32	-11.67	-0.03	11.99	-0.40	0.00
Std. Dev.	23.22	1.58	0.01	5.36	0.10	0.00
Skewness	0.43	-0.59	-0.42	0.43	0.42	1.28
Kurtosis	2.37	3.26	3.46	2.59	1.27	5.89
Jarque-Bera	1.83	2.37	1.48	1.45	6.02	23.56
Observations	39	39	39	39	39	38
ADF test in level (t-statistic)	-2.02	-4.22***	-5.55***	-3.51*	-1.04	-6.72***

Ireland	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	51.98	-6.72	0.01	20.76	-0.32	0.00
Medium	51.56	-6.33	-0.01	20.32	-0.40	0.00
Maximum	74.61	-4.18	0.28	32.31	-0.20	0.01
Minimum	26.76	-10.00	-0.26	11.99	-0.40	0.00
Std. Dev.	12.74	1.49	0.10	5.36	0.10	0.00
Skewness	-0.30	-0.73	0.08	0.43	0.42	1.28
Kurtosis	2.17	2.83	3.57	2.59	1.27	5.89
Jarque-Bera	1.70	3.55	0.57	1.45	6.02	23.56
Observations	39	39	39	39	39	38
ADF test in level (t-statistic)	-1.16	-6.09***	-4.43***	-3.51*	-1.04	-6.72***

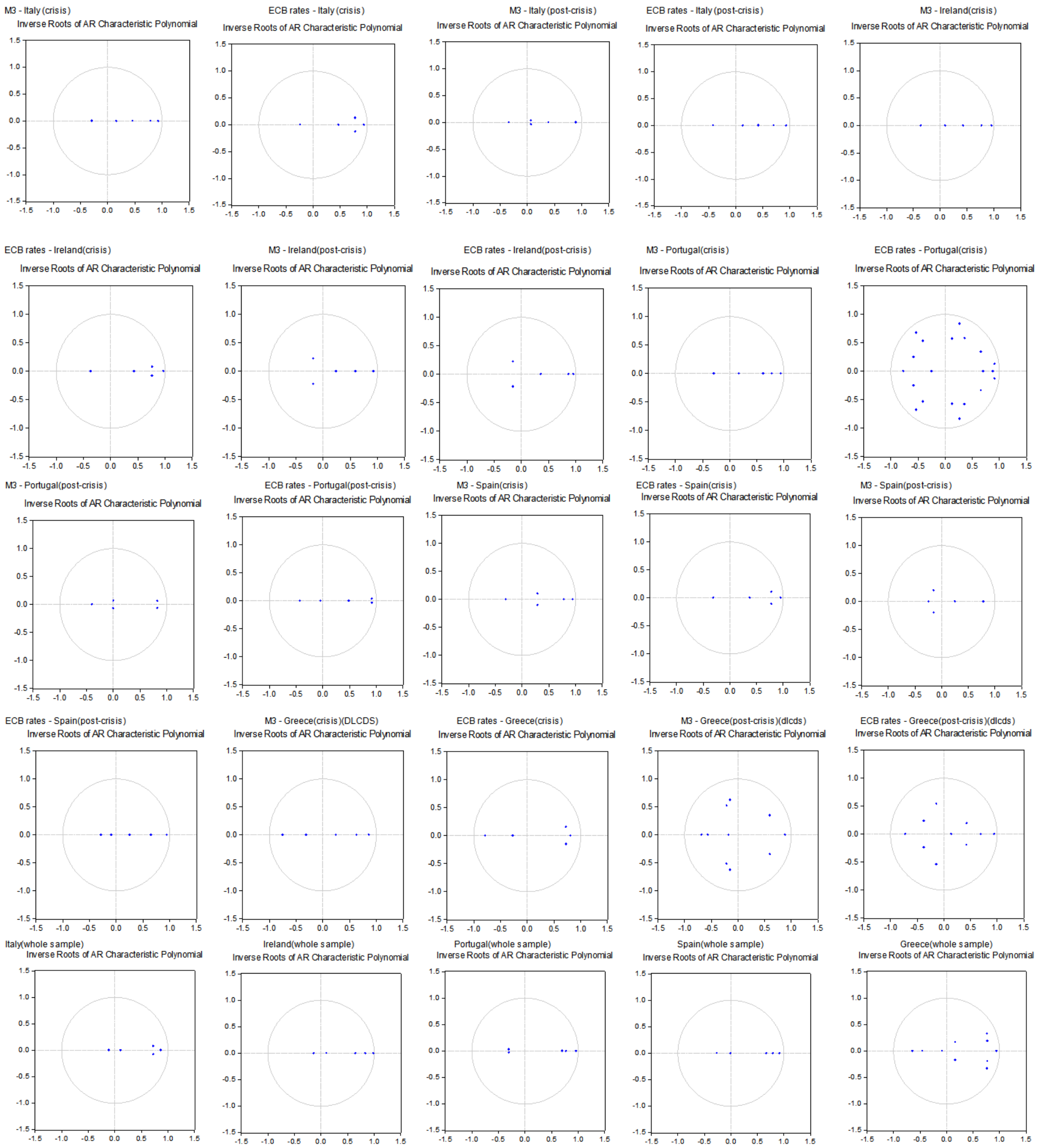
Portugal	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	207.47	-15.48	0.00	20.76	-0.32	0.00
Medium	197.40	-15.00	0.00	20.32	-0.40	0.00
Maximum	308.74	-6.00	0.05	32.31	-0.20	0.01
Minimum	92.16	-25.01	-0.06	11.99	-0.40	0.00
Std. Dev.	59.65	4.70	0.03	5.36	0.10	0.00
Skewness	0.06	-0.29	-0.53	0.43	0.42	1.28
Kurtosis	1.87	2.42	2.94	2.59	1.27	5.89
Jarque-Bera	2.10	1.10	1.85	1.45	6.02	23.56
Observations	39	39	39	39	39	38
ADF test in level (t-statistic)	-0.88	-3.13**	-6.76***	-3.51*	-1.04	-6.72***

Spain	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	84.92	-5.62	0.00	20.76	-0.32	0.00
Medium	86.36	-5.44	0.00	20.32	-0.40	0.00
Maximum	111.82	-2.44	0.02	32.31	-0.20	0.01
Minimum	55.61	-13.81	-0.03	11.99	-0.40	0.00
Std. Dev.	14.40	2.21	0.01	5.36	0.10	0.00
Skewness	-0.11	-1.41	-0.93	0.43	0.42	1.28
Kurtosis	2.47	6.27	4.35	2.59	1.27	5.89
Jarque-Bera	0.54	30.31	8.61	1.45	6.02	23.56
Observations	39	39	39	39	39	38
ADF test in level (t-statistic)	-4.00**	-4.73***	-5.02***	-3.51*	-1.04	-6.72***

Greece	CDS	Bid-ask Spreads	Industrial Production	VSTOXX	Interest Rate	M3
Mean	1,139.62	-316.23	0.00	20.76	-0.32	0.00
Medium	993.07	-157.45	0.00	20.32	-0.40	0.00
Maximum	3,051.91	-32.13	0.03	32.31	-0.20	0.01
Minimum	400.53	-4,834.68	-0.05	11.99	-0.40	0.00
Std. Dev.	629.38	758.40	0.02	5.36	0.10	0.00
Skewness	1.65	-5.63	-0.34	0.43	0.42	1.28
Kurtosis	5.39	34.04	2.13	2.59	1.27	5.89
Jarque-Bera	26.89	1,771.50	1.96	1.45	6.02	23.56
Observations	39	39	38	39	39	38
ADF test in level (t-statistic)	-4.96***	-7.01***	-6.47***	-3.51*	-1.04	-6.72***

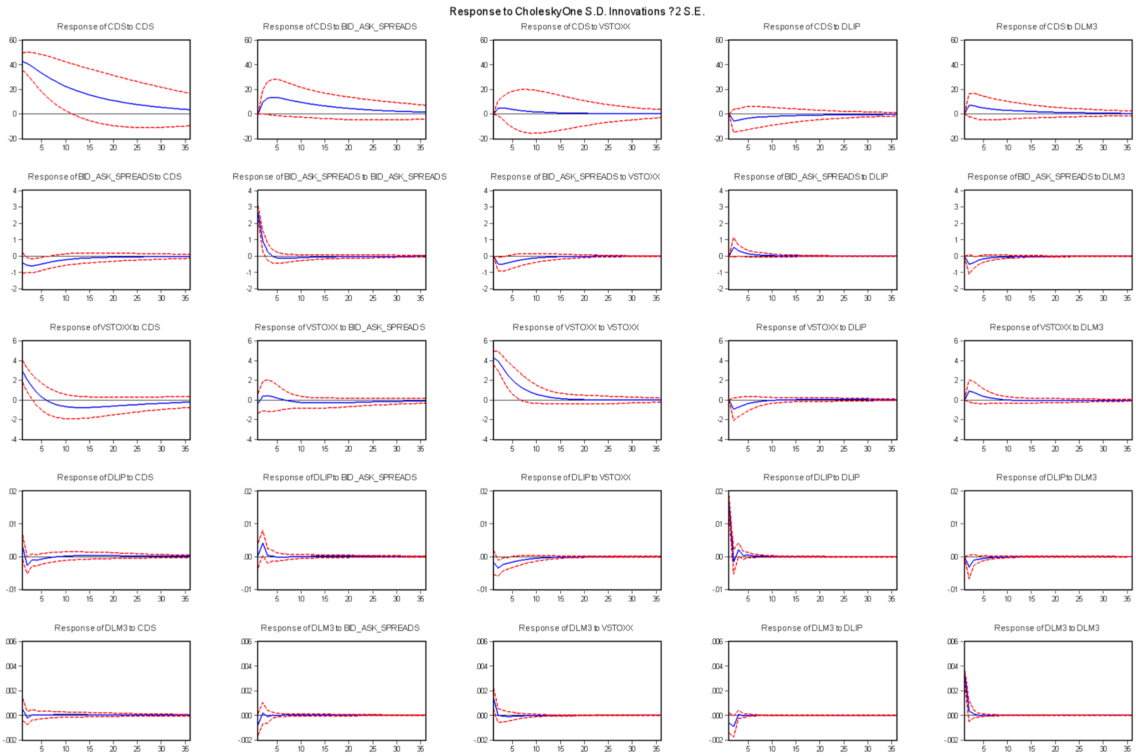
Note: This figure presents the monthly data decription in the post-crisis period (October 2014 to December 2017). Rows of ADF test in level indicate whether series are stationary or not. Stars follow the t-statistics show the significance level: * for 90%, ** for 95%, *** for 99%. The results are rounded to two decimal places.
Source: Thomson Reuters Datastream, and author's calculation.

Figure B3: Unit Root Circles



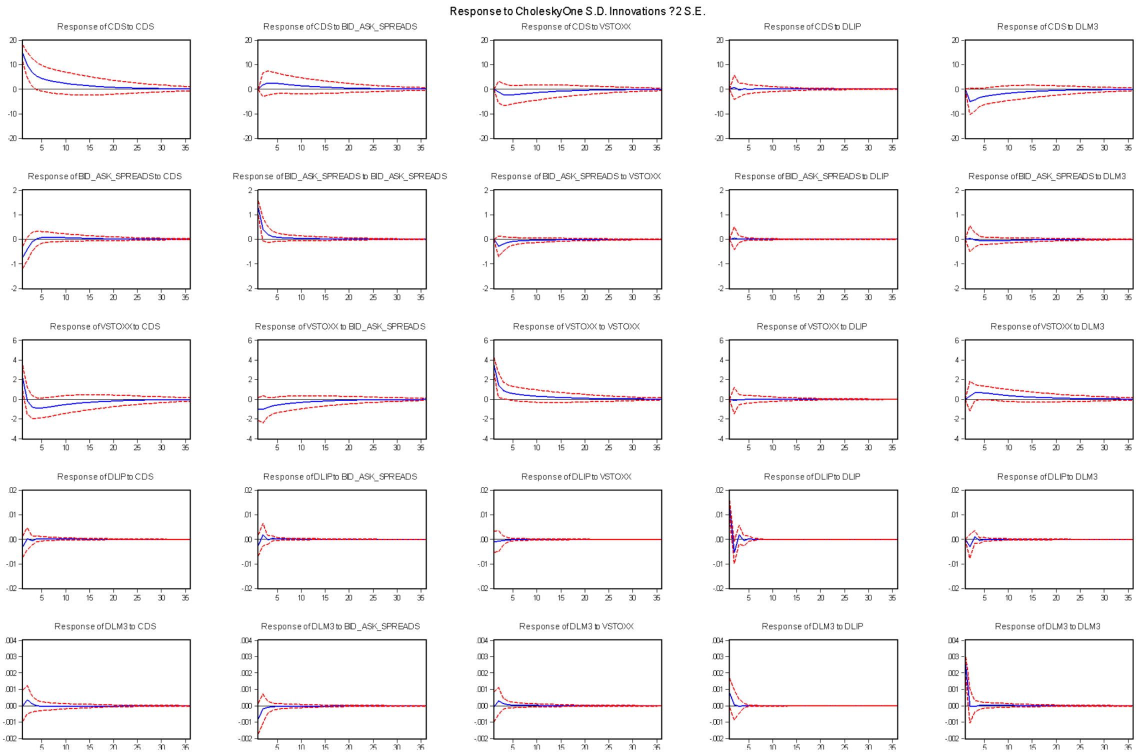
Note: This figure presents five countries' vector autoregressive models unit root tests results. In each country, the crisis period (July 2008 to September 2014) and the post-crisis period (October 2014 to December 2017). In each period, there are interest rate case and monetary aggregate 3 case. The whole sample models of five countries are also tested, and the results are based on European Central Banks's interest rates.
Source: Eviews8.

Figure B4: Impulse Response Functions in M3 Model - Italy, Crisis Period



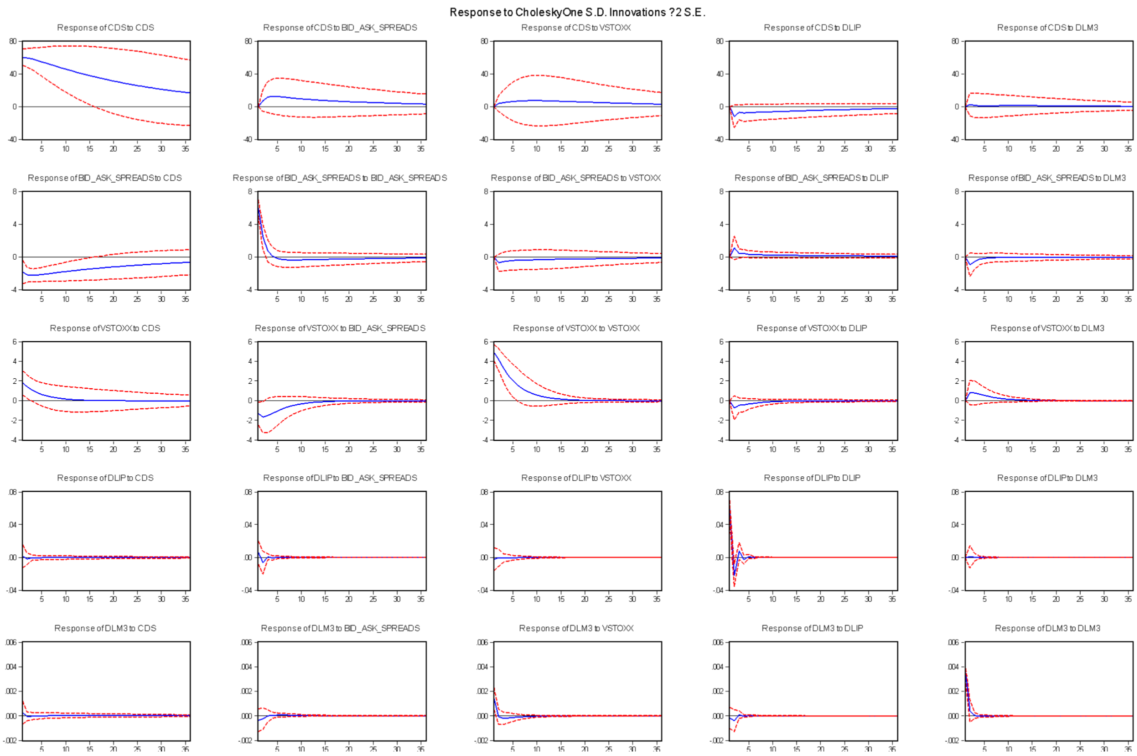
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B5: Impulse Response Functions in M3 Model - Italy, Post-crisis Period



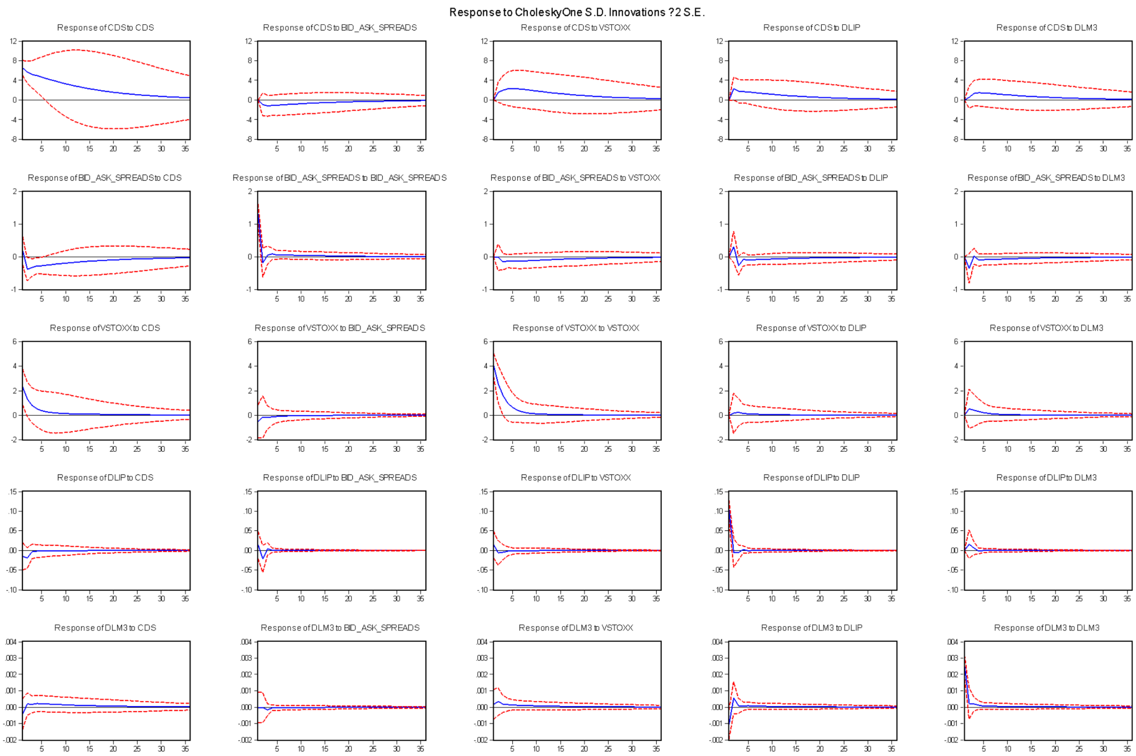
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B6: Impulse Response Functions in M3 Model - Ireland, Crisis Period



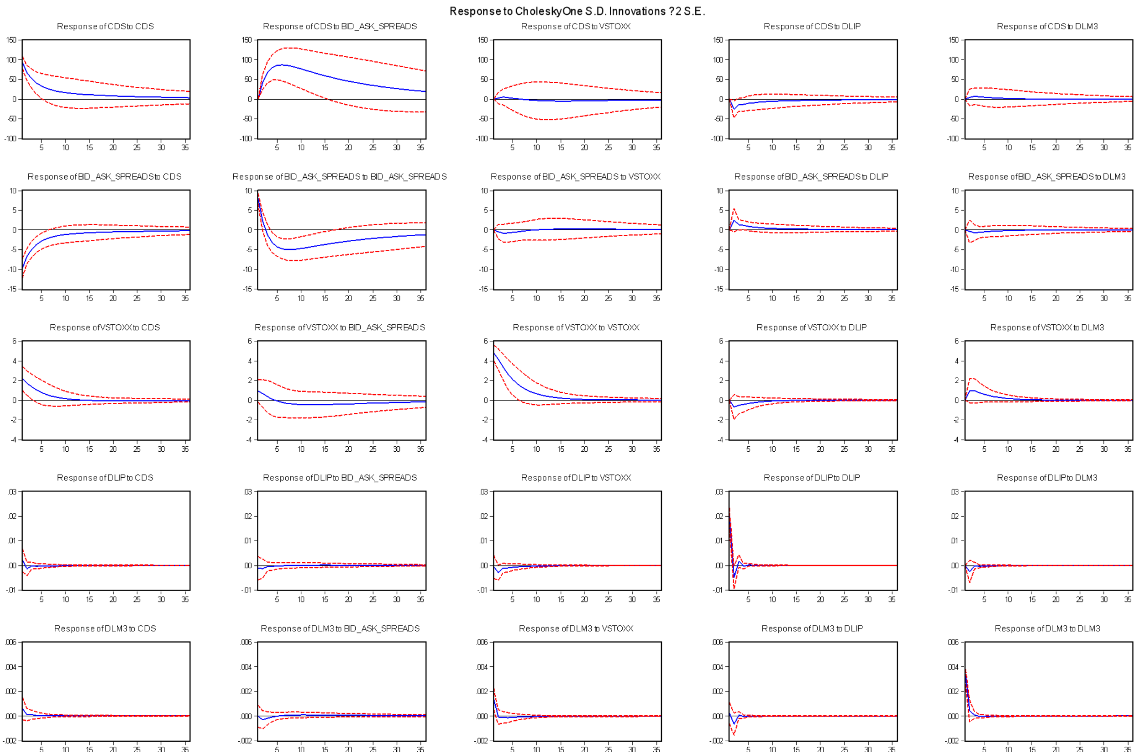
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B7: Impulse Response Functions in M3 Model - Ireland, Post-crisis Period



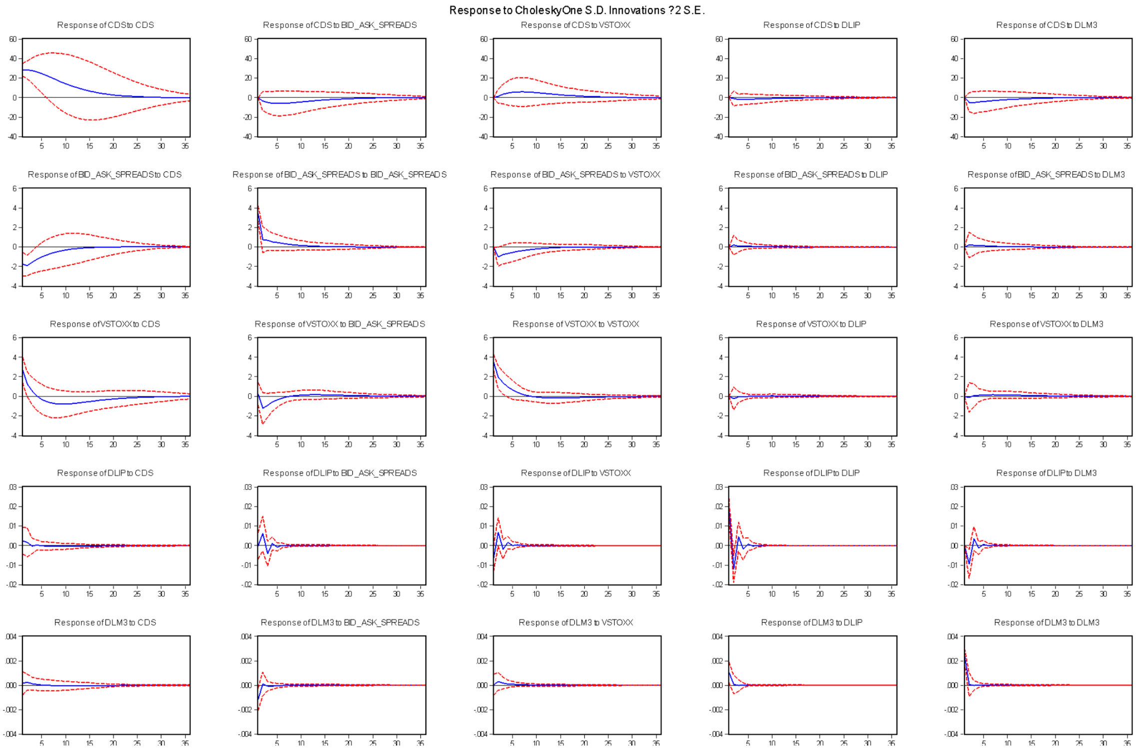
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B8: Impulse Response Functions in M3 Model - Portugal, Crisis Period



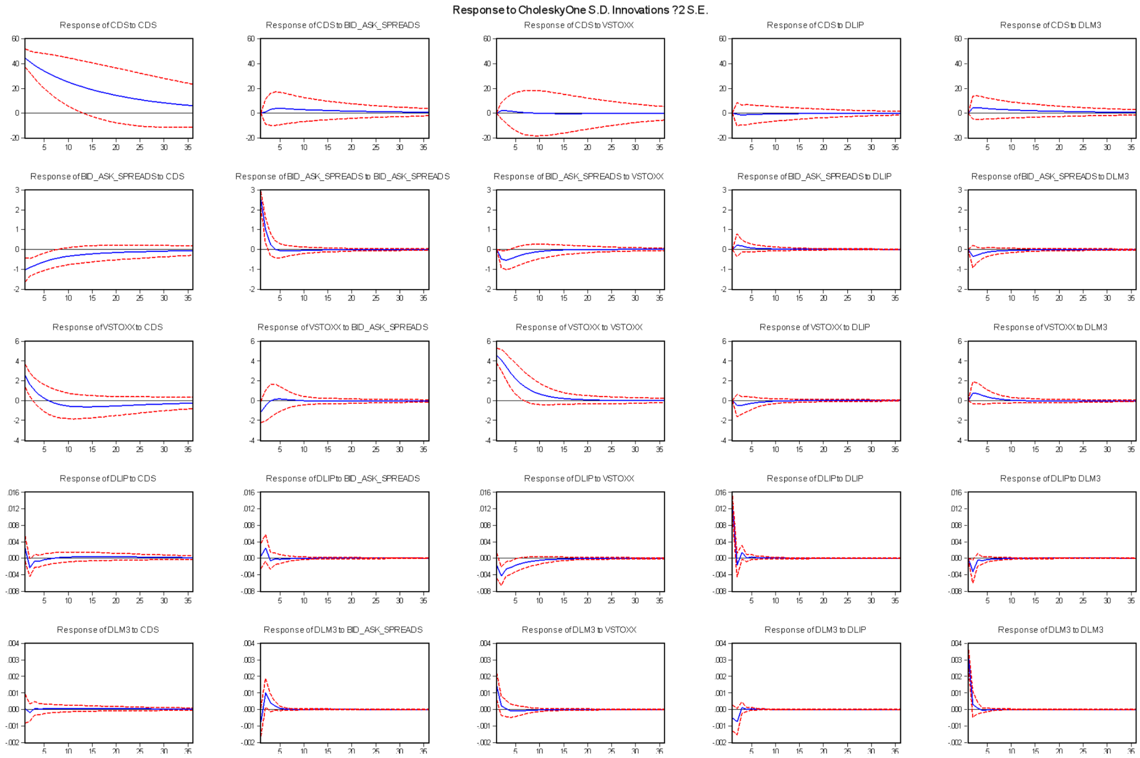
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B9: Impulse Response Functions in M3 Model - Portugal, Post-crisis Period



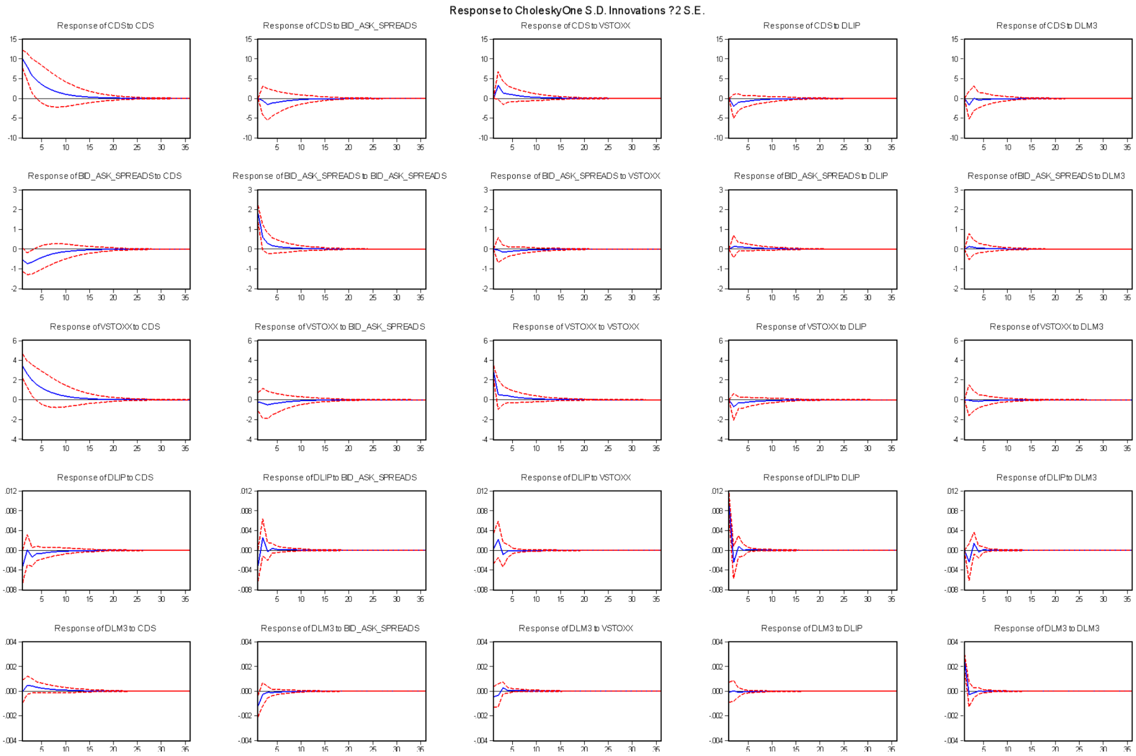
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B10: Impulse Response Functions in M3 Model - Spain, Crisis Period



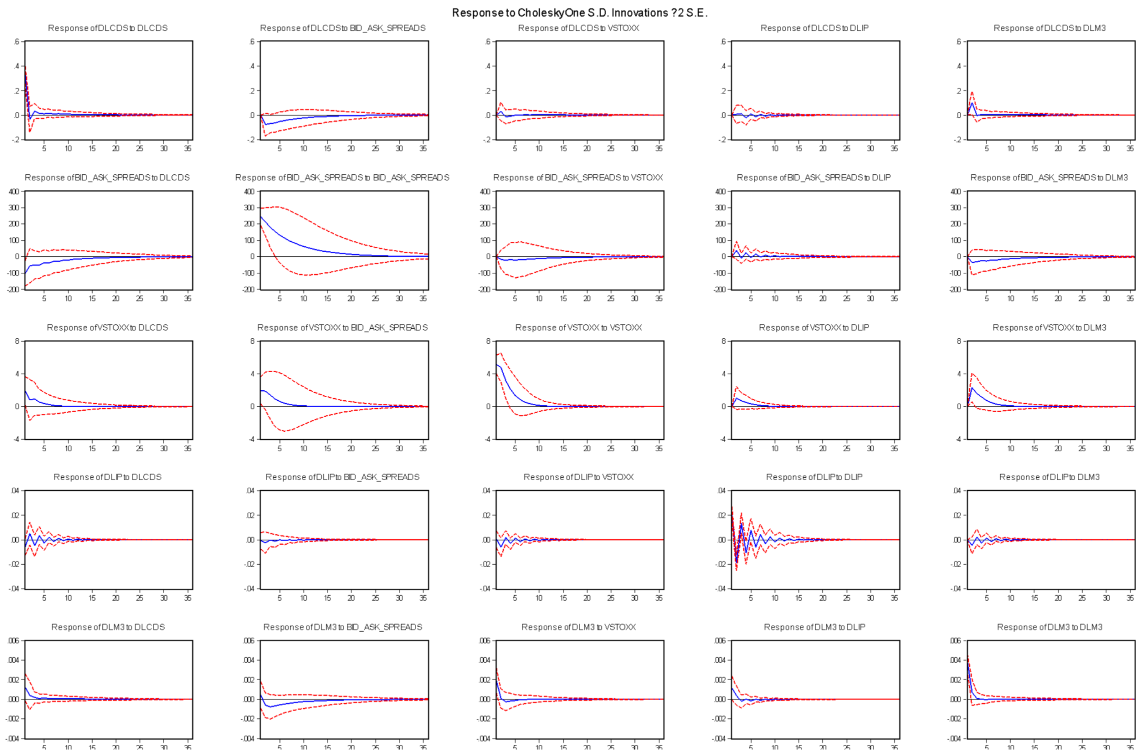
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B11: Impulse Response Functions in M3 Model - Spain, Post-crisis Period



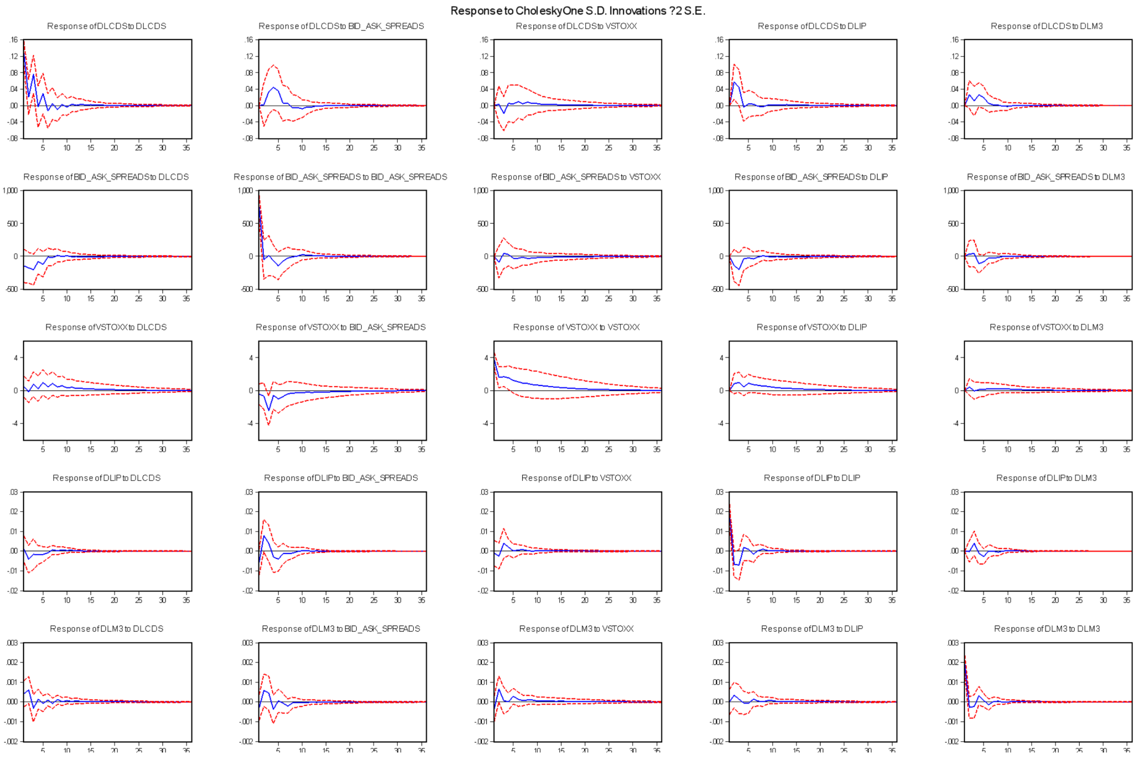
Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B12: Impulse Response Functions in M3 Model - Greece, Crisis Period



Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Figure B13: Impulse Response Functions in M3 Model - Greece, Post-crisis Period



Note: Figure B4 to B13 present the impulse response functions of Italy, Ireland, Portugal, Spain and Greece in both crisis and post-crisis periods. The results come from the vector autoregressive model $CDS_{i,t} = \alpha_i + \sum_{n=1}^{t} \beta_i^1 CDS_{i,t-n} + \sum_{n=1}^{t} \beta_i^2 BIDASK_{i,t-n} + \sum_{n=1}^{t} \beta_i^3 VSTOXX_{i,t-n} + \sum_{n=1}^{t} \beta_i^4 PRODUCTION_{i,t-n} + \sum_{n=1}^{t} \beta_i^5 M3_{i,t-n} + e_{i,t}$. The lags are determined based on the Schwarz criterion and Akaike information criterion. The blueline with red dotted lines (confidence interval) remain in same symbol are treated as significant. DLIP denotes the log-difference of industrial production of this country.
Source: Eviews8.

Table B3: Variance Decomposition of Whole Sample Models - Italy

Variance Decomposition of CDS:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	35.76	100.00	0.00	0.00	0.00	0.00
2.00	36.19	97.67	0.50	1.05	0.26	0.52
3.00	36.47	96.42	0.93	1.67	0.45	0.53
4.00	36.64	95.77	1.15	2.02	0.53	0.53
5.00	36.73	95.43	1.26	2.21	0.56	0.54
6.00	36.78	95.26	1.32	2.31	0.57	0.54
7.00	36.81	95.17	1.34	2.37	0.57	0.54
8.00	36.82	95.13	1.35	2.41	0.57	0.54
9.00	36.83	95.10	1.36	2.43	0.57	0.54
10.00	36.83	95.08	1.36	2.45	0.57	0.54
11.00	36.84	95.07	1.36	2.46	0.58	0.54
12.00	36.84	95.07	1.36	2.46	0.58	0.54

Variance Decomposition of VSTOXX:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	4.27	30.25	69.75	0.00	0.00	0.00
2.00	4.90	29.43	68.10	0.11	1.85	0.52
3.00	5.13	28.64	65.64	0.27	4.94	0.50
4.00	5.26	27.80	62.96	0.37	8.40	0.48
5.00	5.35	26.93	60.67	0.39	11.50	0.51
6.00	5.44	26.15	58.94	0.38	13.96	0.57
7.00	5.51	25.49	57.73	0.38	15.77	0.64
8.00	5.57	24.98	56.89	0.40	17.03	0.70
9.00	5.61	24.58	56.31	0.47	17.89	0.75
10.00	5.65	24.28	55.90	0.56	18.45	0.80
11.00	5.67	24.07	55.61	0.67	18.82	0.83
12.00	5.69	23.91	55.39	0.79	19.05	0.85

Variance Decomposition of Bid-ask Spreads:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.01	7.44	0.12	92.44	0.00	0.00
2.00	0.01	13.12	0.25	86.59	0.00	0.04
3.00	0.01	15.27	0.29	84.34	0.02	0.07
4.00	0.01	16.29	0.29	83.25	0.07	0.09
5.00	0.01	16.84	0.28	82.62	0.15	0.11
6.00	0.01	17.15	0.27	82.22	0.24	0.12
7.00	0.01	17.32	0.26	81.95	0.33	0.13
8.00	0.01	17.42	0.26	81.75	0.43	0.15
9.00	0.01	17.48	0.25	81.60	0.52	0.16
10.00	0.01	17.51	0.26	81.48	0.59	0.16
11.00	0.01	17.52	0.26	81.38	0.66	0.17
12.00	0.01	17.53	0.27	81.31	0.72	0.18

Variance Decomposition of Interest Rate:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.12	2.01	1.10	1.77	95.12	0.00
2.00	0.16	1.92	1.34	1.11	94.72	0.92
3.00	0.19	1.60	3.29	0.80	92.83	1.47
4.00	0.21	1.37	5.47	0.84	90.45	1.87
5.00	0.23	1.23	7.34	1.15	88.13	2.15
6.00	0.24	1.15	8.76	1.64	86.09	2.35
7.00	0.25	1.12	9.79	2.25	84.36	2.48
8.00	0.25	1.12	10.49	2.89	82.92	2.57
9.00	0.26	1.14	10.96	3.53	81.74	2.63
10.00	0.26	1.17	11.25	4.13	80.78	2.67
11.00	0.26	1.22	11.43	4.66	80.00	2.69
12.00	0.27	1.26	11.53	5.13	79.37	2.71

Variance Decomposition of Industrial Production:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	1.94	0.01	2.48	1.99	1.46	94.06
2.00	1.96	0.14	2.49	2.00	1.46	93.91
3.00	1.96	0.17	2.49	2.10	1.46	93.79
4.00	1.96	0.19	2.49	2.15	1.46	93.72
5.00	1.96	0.20	2.49	2.19	1.45	93.67
6.00	1.96	0.21	2.49	2.21	1.45	93.64
7.00	1.96	0.22	2.49	2.23	1.46	93.62
8.00	1.96	0.22	2.48	2.24	1.46	93.60
9.00	1.96	0.22	2.48	2.24	1.46	93.59
10.00	1.96	0.22	2.48	2.25	1.46	93.59
11.00	1.96	0.22	2.48	2.25	1.46	93.58
12.00	1.96	0.23	2.48	2.26	1.46	93.58

Note: Table B3 to B7 present the variance decomposition results of whole sample models (July 2008 to December 2017) for five euro zone periphery countries - Italy, Ireland, Portugal, Spain and Greece. DLIP denotes the log-difference of industrial production of this country. The results are rounded to two decimal places.
Source: Eviews8.

Table B4: Variance Decomposition of Whole Sample Models - Ireland

Variance Decomposition of CDS:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	38.86	100.00	0.00	0.00	0.00	0.00
2.00	39.56	97.87	0.62	0.06	0.30	1.16
3.00	39.66	97.36	0.92	0.09	0.48	1.16
4.00	39.73	97.05	1.08	0.13	0.58	1.15
5.00	39.77	96.86	1.18	0.18	0.63	1.15
6.00	39.80	96.71	1.24	0.24	0.67	1.15
7.00	39.82	96.60	1.27	0.29	0.68	1.15
8.00	39.84	96.51	1.30	0.35	0.69	1.15
9.00	39.86	96.42	1.31	0.42	0.70	1.15
10.00	39.87	96.34	1.33	0.48	0.70	1.14
11.00	39.89	96.27	1.34	0.54	0.70	1.14
12.00	39.90	96.20	1.35	0.61	0.71	1.14

Variance Decomposition of VSTOXX:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	4.39	0.77	99.23	0.00	0.00	0.00
2.00	5.06	0.59	97.76	0.07	1.53	0.05
3.00	5.31	0.55	94.83	0.27	4.30	0.05
4.00	5.44	0.56	91.28	0.66	7.46	0.05
5.00	5.55	0.58	87.77	1.26	10.34	0.05
6.00	5.65	0.59	84.66	2.08	12.62	0.05
7.00	5.75	0.59	82.00	3.09	14.26	0.05
8.00	5.85	0.59	79.75	4.26	15.34	0.05
9.00	5.94	0.58	77.82	5.55	16.00	0.05
10.00	6.02	0.57	76.11	6.94	16.33	0.05
11.00	6.10	0.56	74.57	8.38	16.44	0.05
12.00	6.18	0.55	73.14	9.87	16.39	0.05

Variance Decomposition of Bid-ask Spreads:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.03	0.01	2.61	97.39	0.00	0.00
2.00	0.05	0.07	3.59	96.26	0.01	0.07
3.00	0.06	0.10	4.32	95.50	0.01	0.07
4.00	0.07	0.12	4.87	94.93	0.01	0.07
5.00	0.08	0.13	5.28	94.51	0.01	0.07
6.00	0.08	0.14	5.59	94.20	0.01	0.07
7.00	0.09	0.14	5.82	93.96	0.01	0.07
8.00	0.09	0.15	5.99	93.78	0.01	0.07
9.00	0.10	0.15	6.12	93.64	0.01	0.07
10.00	0.10	0.16	6.21	93.53	0.02	0.07
11.00	0.11	0.16	6.29	93.45	0.03	0.08
12.00	0.11	0.17	6.34	93.38	0.03	0.08

Variance Decomposition of Interest Rate:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.12	0.30	3.46	1.07	95.17	0.00
2.00	0.16	0.77	1.99	2.37	94.68	0.18
3.00	0.19	0.94	2.85	4.19	91.83	0.19
4.00	0.22	0.99	4.45	6.39	87.98	0.19
5.00	0.24	0.97	6.12	8.89	83.83	0.18
6.00	0.25	0.93	7.60	11.62	79.68	0.17
7.00	0.27	0.89	8.80	14.50	75.66	0.16
8.00	0.28	0.83	9.74	17.45	71.82	0.15
9.00	0.29	0.78	10.45	20.41	68.21	0.14
10.00	0.30	0.74	10.97	23.33	64.84	0.13
11.00	0.31	0.70	11.32	26.16	61.70	0.12
12.00	0.32	0.66	11.56	28.87	58.80	0.12

Variance Decomposition of Industrial Production:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	7.42	0.01	0.17	0.82	0.05	98.95
2.00	7.50	0.03	0.38	0.81	0.05	98.72
3.00	7.50	0.03	0.41	0.81	0.05	98.69
4.00	7.50	0.03	0.42	0.81	0.05	98.67
5.00	7.50	0.03	0.43	0.82	0.06	98.66
6.00	7.50	0.03	0.43	0.82	0.06	98.66
7.00	7.50	0.03	0.43	0.82	0.07	98.65
8.00	7.50	0.03	0.43	0.83	0.07	98.64
9.00	7.50	0.03	0.43	0.83	0.07	98.63
10.00	7.50	0.03	0.43	0.84	0.08	98.63
11.00	7.50	0.03	0.43	0.84	0.08	98.62
12.00	7.50	0.03	0.43	0.85	0.08	98.61

Note: Table B3 to B7 present the variance decomposition results of whole sample models (July 2008 to December 2017) for five euro zone periphery countries - Italy, Ireland, Portugal, Spain and Greece. DLIP denotes the log-difference of industrial production of this country. The results are rounded to two decimal places.
Source: Eviews8.

Table B5: Variance Decomposition of Whole Sample Models - Portugal

Variance Decomposition of CDS:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	90.24	100.00	0.00	0.00	0.00	0.00
2.00	93.35	97.79	0.07	0.07	0.01	2.06
3.00	93.85	96.86	0.09	0.12	0.12	2.80
4.00	93.93	96.71	0.11	0.13	0.12	2.94
5.00	93.95	96.66	0.11	0.13	0.14	2.96
6.00	93.96	96.65	0.12	0.13	0.14	2.96
7.00	93.96	96.64	0.12	0.13	0.14	2.96
8.00	93.96	96.64	0.12	0.13	0.14	2.96
9.00	93.96	96.64	0.12	0.13	0.14	2.96
10.00	93.96	96.63	0.12	0.14	0.14	2.96
11.00	93.96	96.63	0.12	0.14	0.14	2.96
12.00	93.96	96.63	0.12	0.14	0.14	2.96

Variance Decomposition of VSTOXX:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	4.25	11.21	88.79	0.00	0.00	0.00
2.00	4.84	9.17	89.23	0.01	1.60	0.00
3.00	5.08	9.27	85.90	0.03	4.74	0.06
4.00	5.21	9.39	82.30	0.09	8.16	0.06
5.00	5.32	9.46	78.98	0.18	11.31	0.07
6.00	5.41	9.47	76.36	0.30	13.80	0.07
7.00	5.50	9.46	74.40	0.45	15.62	0.07
8.00	5.57	9.45	72.97	0.61	16.90	0.07
9.00	5.62	9.45	71.93	0.79	17.76	0.07
10.00	5.67	9.46	71.17	0.98	18.33	0.07
11.00	5.70	9.49	70.59	1.17	18.70	0.07
12.00	5.73	9.52	70.14	1.36	18.92	0.06

Variance Decomposition of Bid-ask Spreads:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.07	18.77	3.83	77.40	0.00	0.00
2.00	0.09	21.16	2.98	75.69	0.00	0.17
3.00	0.11	21.76	2.54	75.52	0.00	0.17
4.00	0.13	22.24	2.26	75.31	0.01	0.18
5.00	0.14	22.56	2.08	75.14	0.03	0.18
6.00	0.15	22.82	1.97	74.97	0.06	0.18
7.00	0.16	23.01	1.90	74.80	0.11	0.18
8.00	0.17	23.17	1.86	74.63	0.16	0.18
9.00	0.17	23.30	1.84	74.47	0.21	0.18
10.00	0.18	23.41	1.83	74.32	0.27	0.18
11.00	0.18	23.49	1.84	74.17	0.32	0.17
12.00	0.19	23.56	1.85	74.03	0.38	0.17

Variance Decomposition of Interest Rate:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.11	1.67	2.00	0.07	96.26	0.00
2.00	0.16	4.94	1.85	0.14	92.70	0.38
3.00	0.19	5.22	4.00	0.38	90.13	0.27
4.00	0.22	5.32	6.41	0.63	87.39	0.25
5.00	0.23	5.41	8.52	0.94	84.91	0.22
6.00	0.24	5.50	10.17	1.28	82.85	0.20
7.00	0.25	5.61	11.41	1.65	81.14	0.19
8.00	0.26	5.73	12.30	2.04	79.75	0.18
9.00	0.27	5.87	12.92	2.44	78.59	0.17
10.00	0.27	6.00	13.35	2.85	77.63	0.17
11.00	0.27	6.14	13.64	3.25	76.81	0.16
12.00	0.27	6.27	13.82	3.65	76.10	0.16

Variance Decomposition of Industrial Production:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	2.13	0.37	0.03	5.10	3.28	91.22
2.00	2.31	0.37	0.05	4.86	4.17	90.56
3.00	2.33	0.50	0.07	4.92	4.08	90.42
4.00	2.34	0.50	0.10	4.90	4.19	90.31
5.00	2.34	0.52	0.12	4.92	4.22	90.22
6.00	2.34	0.53	0.13	4.93	4.25	90.16
7.00	2.34	0.54	0.14	4.94	4.27	90.12
8.00	2.34	0.54	0.15	4.95	4.28	90.08
9.00	2.34	0.55	0.16	4.96	4.29	90.04
10.00	2.34	0.55	0.17	4.97	4.29	90.02
11.00	2.34	0.56	0.17	4.98	4.30	90.00
12.00	2.34	0.56	0.17	4.99	4.30	89.98

Note: Table B3 to B7 present the variance decomposition results of whole sample models (July 2008 to December 2017) for five euro zone periphery countries - Italy, Ireland, Portugal, Spain and Greece. DLIP denotes the log-difference of industrial production of this country. The results are rounded to two decimal places.
Source: Eviews8.

Table B6: Variance Decomposition of Whole Sample Models - Spain

Variance Decomposition of CDS:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	35.61	100.00	0.00	0.00	0.00	0.00
2.00	35.86	98.76	0.50	0.27	0.27	0.20
3.00	35.99	98.15	0.79	0.52	0.35	0.20
4.00	36.07	97.82	0.90	0.69	0.38	0.20
5.00	36.11	97.61	0.96	0.83	0.40	0.20
6.00	36.14	97.47	0.98	0.94	0.40	0.20
7.00	36.16	97.37	0.99	1.03	0.40	0.20
8.00	36.18	97.29	1.00	1.11	0.40	0.20
9.00	36.19	97.22	1.00	1.17	0.40	0.20
10.00	36.21	97.17	1.00	1.22	0.40	0.20
11.00	36.21	97.13	1.00	1.26	0.40	0.20
12.00	36.22	97.09	1.00	1.30	0.40	0.20

Variance Decomposition of VSTOXX:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	4.24	18.72	81.28	0.00	0.00	0.00
2.00	4.90	17.35	79.24	0.02	2.23	1.15
3.00	5.12	16.65	76.16	0.10	5.70	1.39
4.00	5.26	15.96	72.69	0.17	9.56	1.62
5.00	5.37	15.34	69.77	0.21	12.95	1.74
6.00	5.46	14.82	67.56	0.24	15.60	1.80
7.00	5.54	14.41	66.00	0.24	17.53	1.82
8.00	5.60	14.11	64.93	0.24	18.89	1.83
9.00	5.65	13.89	64.22	0.23	19.82	1.83
10.00	5.68	13.74	63.75	0.23	20.45	1.83
11.00	5.71	13.63	63.43	0.24	20.87	1.83
12.00	5.72	13.56	63.23	0.24	21.15	1.82

Variance Decomposition of Bid-ask Spreads:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.01	1.16	1.18	97.66	0.00	0.00
2.00	0.01	5.66	1.07	93.05	0.00	0.22
3.00	0.01	7.04	0.97	91.79	0.01	0.19
4.00	0.01	7.65	0.88	91.26	0.02	0.19
5.00	0.01	7.99	0.81	90.99	0.03	0.19
6.00	0.01	8.19	0.76	90.83	0.05	0.18
7.00	0.02	8.32	0.71	90.73	0.06	0.18
8.00	0.02	8.41	0.68	90.66	0.08	0.18
9.00	0.02	8.47	0.65	90.61	0.10	0.17
10.00	0.02	8.52	0.62	90.57	0.11	0.17
11.00	0.02	8.55	0.61	90.55	0.12	0.17
12.00	0.02	8.58	0.59	90.52	0.14	0.17

Variance Decomposition of Interest Rate:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.11	0.14	1.35	0.11	98.40	0.00
2.00	0.16	0.40	1.13	0.08	95.18	3.21
3.00	0.19	0.29	2.97	0.10	93.66	2.98
4.00	0.22	0.24	4.97	0.18	91.73	2.88
5.00	0.23	0.22	6.70	0.31	90.02	2.75
6.00	0.25	0.21	8.05	0.48	88.61	2.64
7.00	0.25	0.21	9.04	0.69	87.50	2.56
8.00	0.26	0.20	9.74	0.92	86.63	2.50
9.00	0.26	0.20	10.22	1.18	85.95	2.45
10.00	0.27	0.19	10.54	1.45	85.40	2.42
11.00	0.27	0.19	10.75	1.72	84.95	2.39
12.00	0.27	0.19	10.87	1.99	84.58	2.37

Variance Decomposition of Industrial Production:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	1.22	3.51	0.04	1.00	0.87	94.58
2.00	1.30	3.88	1.29	1.20	2.49	91.14
3.00	1.30	3.86	1.29	1.21	3.14	90.49
4.00	1.31	3.85	1.28	1.26	3.95	89.66
5.00	1.32	3.83	1.31	1.29	4.56	89.01
6.00	1.32	3.81	1.37	1.34	5.04	88.45
7.00	1.32	3.79	1.44	1.38	5.39	88.01
8.00	1.33	3.77	1.50	1.43	5.64	87.66
9.00	1.33	3.76	1.55	1.47	5.81	87.40
10.00	1.33	3.76	1.59	1.52	5.93	87.20
11.00	1.33	3.75	1.62	1.57	6.01	87.04
12.00	1.33	3.75	1.65	1.61	6.07	86.93

Note: Table B3 to B7 present the variance decomposition results of whole sample models (July 2008 to December 2017) for five euro zone periphery countries - Italy, Ireland, Portugal, Spain and Greece. DLIP denotes the log-difference of industrial production of this country. The results are rounded to two decimal places.
Source: Eviews8.

Table B7: Variance Decomposition of Whole Sample Models - Greece

Variance Decomposition of CDS:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.23	100.00	0.00	0.00	0.00	0.00
2.00	0.25	91.77	0.15	3.21	3.62	1.25
3.00	0.26	87.65	1.56	5.92	3.67	1.21
4.00	0.27	81.56	2.07	11.11	4.05	1.21
5.00	0.29	73.91	2.06	18.95	3.71	1.38
6.00	0.30	68.53	1.90	24.66	3.53	1.38
7.00	0.31	64.86	1.93	28.08	3.37	1.77
8.00	0.31	62.93	2.21	29.51	3.34	2.01
9.00	0.32	61.94	2.53	29.78	3.36	2.38
10.00	0.32	61.49	2.81	29.65	3.45	2.60
11.00	0.32	61.21	2.93	29.53	3.54	2.78
12.00	0.32	60.98	2.96	29.56	3.64	2.86

Variance Decomposition of VSTOXX:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	4.58	6.70	93.30	0.00	0.00	0.00
2.00	5.26	5.20	91.84	0.81	2.14	0.01
3.00	5.57	4.71	88.57	0.95	5.57	0.19
4.00	5.77	4.41	84.83	0.94	9.53	0.29
5.00	5.90	4.23	81.53	0.90	12.97	0.37
6.00	5.99	4.11	79.11	0.87	15.52	0.39
7.00	6.05	4.04	77.57	0.86	17.15	0.38
8.00	6.09	4.00	76.70	0.86	18.07	0.38
9.00	6.11	3.98	76.26	0.86	18.49	0.40
10.00	6.13	3.99	76.06	0.85	18.65	0.45
11.00	6.14	4.00	75.95	0.85	18.67	0.52
12.00	6.15	4.02	75.85	0.86	18.65	0.62

Variance Decomposition of Bid-ask Spreads:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.34	5.56	3.03	91.41	0.00	0.00
2.00	0.62	9.16	1.74	85.86	0.00	3.24
3.00	0.80	8.21	2.99	84.37	0.27	4.16
4.00	0.93	7.68	4.45	80.90	0.56	6.41
5.00	1.00	7.22	6.09	77.51	1.12	8.06
6.00	1.05	6.88	7.32	74.08	1.77	9.95
7.00	1.07	6.66	8.08	71.35	2.55	11.36
8.00	1.09	6.50	8.34	69.39	3.28	12.49
9.00	1.10	6.39	8.31	68.23	3.90	13.17
10.00	1.11	6.31	8.21	67.57	4.33	13.59
11.00	1.11	6.26	8.18	67.18	4.58	13.80
12.00	1.12	6.24	8.26	66.90	4.70	13.91

Variance Decomposition of Interest Rate:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	0.12	2.07	3.53	2.19	92.20	0.00
2.00	0.18	2.26	6.31	0.97	90.08	0.38
3.00	0.22	1.77	4.50	1.89	91.57	0.26
4.00	0.25	1.48	3.83	4.67	89.78	0.25
5.00	0.26	1.31	3.86	7.82	86.80	0.21
6.00	0.27	1.20	4.09	10.18	84.33	0.20
7.00	0.28	1.16	4.25	11.42	82.92	0.24
8.00	0.28	1.21	4.37	11.77	82.32	0.33
9.00	0.29	1.33	4.44	11.71	82.01	0.51
10.00	0.29	1.54	4.47	11.69	81.53	0.78
11.00	0.29	1.77	4.47	11.92	80.68	1.16
12.00	0.29	2.01	4.46	12.39	79.52	1.61

Variance Decomposition of Industrial Production:

Period	S.E.	CDS	VSTOXX	Bid-ask Spreads	Interest Rate	Industrial Production
1.00	2.61	0.04	0.91	0.55	4.48	94.02
2.00	2.83	7.60	1.36	0.79	3.96	86.28
3.00	3.34	7.08	1.00	0.63	3.42	87.87
4.00	3.53	9.62	0.92	0.87	3.08	85.51
5.00	3.81	10.16	0.85	1.48	2.72	84.79
6.00	4.01	11.56	0.78	2.84	2.46	82.37
7.00	4.24	12.13	0.72	4.65	2.20	80.29
8.00	4.45	12.82	0.66	6.79	2.00	77.74
9.00	4.66	13.12	0.60	8.79	1.83	75.66
10.00	4.84	13.38	0.57	10.54	1.70	73.81
11.00	5.01	13.48	0.56	11.87	1.59	72.49
12.00	5.15	13.57	0.57	12.83	1.52	71.51

Note: Table B3 to B7 present the variance decomposition results of whole sample models (July 2008 to December 2017) for five euro zone periphery countries - Italy, Ireland, Portugal, Spain and Greece. DLIP denotes the log-difference of industrial production of this country. The results are rounded to two decimal places.
Source: Eviews8.

Chapter 4

GIVE OR RECEIVE? SPILLOVER ANALYSIS OF SOVEREIGN CREDIT DEFAULT SWAPS SINCE THE GLOBAL FINANCIAL CRISIS

Abstract

Chapter 4 aims to discuss the sovereign credit default swaps markets spillover effects in the Eurozone between core and periphery countries since Global Financial Crisis in 2008 to the COVID-19 pandemic phase. We employed the Diebold and Yilmaz (2009) spillover index approach based on a vector autoregressive model. From the results of spillover index and time-varying total and pairwise spillovers of the daily credit default swap spreads growth rates, we find that spillovers exhibit different behavior in distinct stress environments, with stronger interconnections between individual sovereigns during the GFC and the Eurozone debt crisis compared to the pandemic period; Spain and Portugal emerge as the primary spillover transmitters in all phases. Our empirical findings contribute to broaden the contagion research of sovereign credit markets since European debt crisis, and provide several important insights for portfolio managers, policymakers, and investors.

4.1 Introduction

In late 2009, the credit rating agency Fitch lowered the Greek sovereign credit rating from A- to BBB+ and issued a negative outlook on the country's public finances. This event is widely regarded as the trigger for the Greek sovereign debt crisis. Subsequently, in early 2010, the crisis escalated as the Greek government became unable to repay its loans to banks, financial institutions, and investment funds. The resulting credit event damaged the credit of the Eurozone, causing economic turmoil that spread to other EMU countries.

While the inability to meet financial obligations was the immediate cause of the crisis, deeper underlying issues rooted in specific fundamental problems of the countries involved were also at play. For decades, Greece had been grappling with balance-of-pays deficits and accumulating public debt, which ultimately contributed to the crisis. As Gill (2018) notes, it is essential to delve into these country-specific issues to fully understand the origins of the crisis.

The Global Financial Crisis (GFC) had an impact on the European sovereign credit market, leading to a slight rise in sovereign CDS and a decrease in sovereign credit. However, the effects of the sovereign debt crisis were more significant in Eurozone than those of the 2007-2009 GFC. The Greek sovereign credit default swap (CDS) yields rose sharply starting in late 2009, peaking in March 2012. The contagion and spillover effects of growing sovereign CDS yields also affected many other countries in Europe, including Italy, Ireland, Spain, and Portugal. These countries experienced significant instability and were among the primary sufferers during the crisis. Unemployment rates in Spain and Greece reached 26.9% and 26.8%, respectively, by May 2013.

The European Troika, consisting of the European Central Bank (ECB), European Commission (EC), and International Monetary Fund (IMF), provided a bailout and policy rate changes, resulting in the recovery of most countries' sovereign credit markets by early 2014. Meanwhile, the sovereign credit markets of many European countries were affected by the spillover effects from the most severely affected countries during the European debt crisis.

In financial markets, risks can arise due to contractual linkages among banks, where the devaluation of unrepayable assets by one bank can have repercussions for others (Allen & Gale, 2000). Zooming this theory in the sovereign credit market, the inability of the Greek government to repay loans had a significant impact on other countries' credit ratings, mainly due to the characteristics of the EMU. Previous crises have demonstrated that contagion and spillover effects from one region's turmoil can lead to higher costs for other regions, governments, and investors. Early research on the East Asian crisis has provided evidence on spillover effects systematic study, which saw the collapse of Thailand's currency in 1997, has explored how contagion can be transmitted through different channels, such as trade links and financial transactions (Walker, 1998). Walker (1998) identified three significant effects of financial channels: liquidity effects, financial volatility, and bandwagon effects. Sovereign CDS, as a credit derivative, are also known to be affected during financial market turmoil, and are commonly used to measure national credit. Many studies have focused on the spillover effects of sovereign credit within the Eurozone, including the different degrees of contagion among countries when hit by the crisis. Since the Greek government defaulted and the European sovereign debt crisis occurred, investors and governments have paid close attention to changes in sovereign credit and their potential financial and economic impact.

The GFC and the European debt crisis are examples of crises that had a wide-ranging impact on the Eurozone economy and sovereign credit markets. Similarly, the global pandemic crisis that began in early 2020 has had a significant impact on the Eurozone economy and sovereign credit market. The social control measures taken to prevent the spread of the pandemic have hindered productivity, leading to a sluggish economy. Additionally, governments have invested in responding to the pandemic, increasing government debt and reducing sovereign credit. The impact of the black swan/footnoteBlack swan event refers to an unexpected, highly impactful occurrence. I.e. the financial crash of the U.S. housing market in 2008, and COVID-19 spreads. of the pandemic has also caused unprecedented fluctuations in the US stock market. In the sovereign credit market, which is subject to both internal and external shocks, we assume the spillover effects may behave differently during crisis periods.

The main research questions for this chapter are: How has the spillover effect of the European sovereign credit market changed since the 2008 economic crisis? What are the differences in the spillover effects of European sovereign credit markets during crisis periods compared to non-crisis periods? What is the difference in the spillover effects of the European sovereign credit market during different crisis periods in the past, including the economic and debt crisis and the global pandemic crisis period? These questions will help us gain insights into the spillover effects of the European sovereign credit market in different periods and the impact of crisis events on the market.

4.2 Literature Review

The spillover index was initially proposed by Diebold and Yilmaz (2009) based on a vector autoregressive model in the broad tradition of Engle et al. (1990). This methodology conveys important and valuable information on contagion by measuring return and spillovers on variance decomposition. In a later study, Diebold and Yilmaz (2012) developed a generalized VAR model (Koop et al., 1996; Pesaran & Shin, 1998) to overcome the limitation of variable ordering. The spillover index methodology has been widely applied to individual assets, asset portfolios, and asset markets. For example, the Diebold and Yilmaz (2012) index has been applied to cross-market spillovers (Antonakakis et al., 2018; Antonakakis et al., 2019), stock market spillovers (Yarovaya et al., 2016; Shahzad et al., 2017; Liow and Song, 2020), foreign exchange market spillovers (Antonakakis, 2012; Wen & Wang, 2020; Chang et al., 2022), bond market spillovers (Antonakakis & Vergos, 2013; Ahmad et al., 2018; Conefrey & Cronin, 2015), commodity market spillovers (Antonakakis et al., 2017; Kang et al., 2017; Gong & Xu, 2022), and cryptocurrency market spillovers (Corbet et al., 2018; Yi et al., 2018).

In this chapter, we aim to study the performance of the contagion effect in the sovereign CDS market between core and peripheral countries in the euro area since the GFC. To achieve this, we will use a modified spillover model (Diebold and Yilmaz, 2012) that is not limited to variable ordering.

The application of the spillover index methodology to the sovereign credit market is not uncommon. Claeys and Vašíček (2012) focused on Central and Eastern European (CEE) countries by applying forecast error variance decomposition. They found that the impact of the spillover is often more substantial on bond yields and spreads of other sovereigns than on domestic factors. They also observed that the spillover impacts from downgraded sovereign ratings in low-grade levels are particularly strong to bond spreads. The findings from Claeys and Vašíček (2012) suggest high contagion among sovereign bond markets, with higher impacts in riskier markets. However, it is worth exploring whether the impact of sovereign ratings applies to the sovereign CDS market. Another study aimed at Latin America (Ballester & González-Urteaga, 2017) provided evidence that discrete time series, such as credit ratings, could be analyzed through a spillover index. They concluded that CDS spreads had already reflected the information before positive or negative rating announcements occurred. Therefore, due to the rapid response of the secondary market, sovereign CDS spreads can reflect changes in sovereign credit faster than sovereign ratings, which means it is more practical to apply the CDS yields on sovereign credit issues than credit ratings. Moreover, Cho, Choi, and Chung (2014) measured the contagion among seven Asian countries' sovereign CDS yields using the spillover index model of Diebold and Yilmaz (2009). They concluded that there were more contamination effects under economic and financial distress, such as the Lehman Brothers bankruptcy, the European financial crisis, and the US credit downgrade. This implies that the degree of spillover effects is different under different external environments, which inspires us to compare the spillover effects of different stress periods.

In their analysis of the contagion and spillover effects of sovereign CDS worldwide, Boyrie and Pavlova (2016) employ principal components and spillover index methods to investigate the co-movement and contamination among emerging credit markets. Their findings indicate that there are contagions between the European and emerging markets, and that the VIX volatility index contributes 4% to 7% spillovers to emerging credit markets, suggesting that a global financial factor drives a significant portion of contagion effects. This is consistent with Adam's (2013) conclusion that nearly half of the variance of global credit spreads can be attributed to a single component, and that intra-regional spillover effects are also significant. The study (Adam, 2013) further shows that market liquidity is a key driver of sovereign CDS yields, with daily data from Eurozone and EMEA[1] countries revealing that liquidity accounts for 67% of the variation in these spreads. This indicates that credit markets are susceptible to spillover effects, with the spillover effects being more pronounced within the euro area. Given that spillover effects appear to be more pronounced within the region, it is worth exploring whether there are different regions or groups within the Eurozone that contribute to greater spillover effects compared to other countries.

Several studies have examined the spillover effects within the Eurozone. For instance, De Santis (2012) found that the sovereign credit risk of Greece had severe spillover impacts on other PIIGS countries, France, and Belgium during the period 2008-2011. Antonakakis and Vergos (2013) investigated the spillover effects between core (Austria, France, Belgium, and Netherlands) and peripheral (Portugal, Ireland, Italy, Spain, and Greece) Eurozone countries from 2007 to 2012. They concluded that there were higher magnitude spillover effects within the core and peripheral groups than between them, and the impacts from peripheral countries to core countries were higher than vice versa. Fernández-Rodríguez et al. (2015) also found similar results, suggesting that peripheral countries in the Eurozone were the dominant transmitters of the crisis during the period, but they were also major receivers of credibility impacts from core countries in the pre-crisis period. Bostanci and Yilmaz (2020) analyzed the global network structure of sovereign credit risk using sovereign CDS data from 38 countries. They reported a strong contagion among EMU countries from 2009 to 2014, with Portugal, Ireland, Italy, and Spain tightly connected with the western European countries group, especially Belgium, France, and Austria. Overall, the literature suggest that the euro area can be divided into two groups: the core countries with

[1]EMEA: Europe, the Middle East, and Africa.

solid economic foundations and the peripheral countries hit by the impact of the crisis. In this chapter, we build on the previous research and extend the analysis to the post-crisis and pandemic periods. We assume that spillovers from peripheral countries are heavier overall than from core countries, and that spillovers within each group are stronger than spillovers across the two groups. The analysis of spillover effects within these groups provides important insights into the transmission mechanisms of sovereign credit risk in the Eurozone.

The European sovereign debt crisis had a significant impact on both sovereign credit markets and sovereign bond markets. Alter and Beyer (2014) conducted an analysis to quantify the spillovers between European sovereign credit markets and banks, building on the framework of Diebold and Yilmaz (2011). Their findings suggest that high levels of contagion and co-movements were observed in April 2010, August 2011, and June 2012, coinciding with policy events such as the implementation of IMF/EU programs, the establishment of the European Financial Stability Facility (EFSF), and the decisions of two long-term refinancing operations (LTROs). This indicates that policy events related to the research target market are likely to enhance the spillover effect, reflecting the risk aversion psychology of investors. During times of crisis, events related to the economy and sovereign credit tend to occur one after another, leading to stronger spillover effects compared to non-crisis periods. Research conducted during the COVID-19 pandemic period also provides evidence of spillover effects. Choi (2022) studied the dynamic connectedness of stock markets between Northeast Asian countries and the United States, concluding that interdependence increased during both the GFC and the COVID-19 pandemic periods, with stronger interdependence during the GFC than during the pandemic period. Rout and Mallick (2022) also found that the shock spillover of bond yields amplified significantly during the COVID-19 period compared to the pre-COVID-19 period in a sample of eight major world economies. Given that the direct impacts on sovereign credit from the GFC and the European sovereign debt crisis, different from the pandemic affects more economic fundamentals, we assume that during the GFC and the European sovereign debt crisis periods, spillover effects in the euro area were highest within the region, followed by the pandemic period, and lowest during non-crisis periods.

4.3 Methodology

This analysis is based on the directional spillover approach introduced by Diebold and Yilmaz (2012), which exploits the generalized framework of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998), and produced a variance decomposition (KPPS) invariant to ordering.

Consider a covariance stationary N-variables VAR model of P_{th} order:

$$y_t = \sum_{i=1}^{P} \Phi_i x_{t-i} + \varepsilon_{\mathrm{t}} \tag{4.1}$$

where y_t is a vector of endogenous variables of nine European countries' sovereign CDS yields daily growth rates; $\Phi_{\mathrm{i}}, i = 1, ..., P$ are N*N parameter matrices and ε_t ~(0,Σ) is assumed to be a vector of independently and identically distributed disturbances. t is the time index, ranging from July 2008 to December 2020.

This stationary VAR model could be turned into a moving average process which could present the dynamic of this system: $\mathrm{y}_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$ where A_i is an N*N coefficient matrix and is recursively defined as follows:

$$\mathrm{A}_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + ... + \Phi_p A_{i-p} \tag{4.2}$$

with A_0 an N*N identity matrix and $\mathrm{A}_i = 0$ for i < 0.

Basing on the variance decomposition, the forecast error variances of each variable could be recovered from the various system shocks. Specifically, the fraction of the H-step-ahead error variance in forecasting y_i due to shocks to y_j, $\forall \mathrm{j} \neq i$ for each i.

Diebold and Yilmaz (2012) defined own variance shares to be the fractions of the H-step-ahead error variances in forecasting y_i due to the shocks to it, for $\imath = 1, 2, ..., N$, and spillovers (cross variance shares) to be the fraction of the H-step-ahead error variances in forecasting different countries' rates due to the shocks to y_j, for that $i \neq j$.

In the generalized framework, the H-step-ahead forecast error variance decomposition could be presented as:

$$\theta^g_{ij}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \sum e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \sum A_h' e_i\right)} \tag{4.3}$$

Where $\sum$ is the variance matrix for the error vector ε, σ_{ii} is the standard deviation of the error term for the ith equation, and e_i is the selection vector with 1 as the ith element, and 0 otherwise. According to the characteristics of generalized FEVD, the sum of the elements of each row of the variance decomposition table is not equal to 1: $\sum_{j=1}^{N} \theta^g_{ij}(H) \neq 1$. And each entry of the variance decomposition matrix could be normalized by the row sum as:

$$\tilde{\theta}^g_{ij}(H) = \frac{\theta^g_{ij}(H)}{\sum_{j=1}^{N} \theta^g_{ij}(H)} \tag{4.4}$$

where $\sum_{j=1}^{N} \tilde{\theta}^g_{ij}(\mathrm{H}) = 1$ and $\sum_{i,j=1}^{N} \tilde{\theta}^g_{ij}(H) = N$.

On the basis of KPPS variance decomposition, the total spillover index could be constructed as:

$$S^g(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}^g_{ij}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}^g_{ij}(H)} .100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}^g_{ij}(H)}{N} .100 \tag{4.5}$$

This index measures the contributions from the spillovers of shocks across sovereign CDS markets to the total forecast error variance.

Since the ordering of variables in the KPPS process is constant, the generalized variance decomposition of the normalized elements of the position matrix can be used to calculate the direction spillovers. Here, the directional spillovers received by market i from all other markets j as:

$$S^g_{i\bullet}(H) = \frac{\sum\limits_{\substack{j=1 \\ j\neq i}}^{N} \tilde{\theta}^g_{ij}(H)}{\sum\limits_{j=1}^{N} \tilde{\theta}^g_{ij}(H)}.100 \tag{4.6}$$

Similarly, the directional spillovers transmitted by market i to all other markets j is:

$$S^g_{\bullet i}(H) = \frac{\sum\limits_{\substack{j=1 \\ j\neq i}}^{N} \tilde{\theta}^g_{ji}(H)}{\sum\limits_{j=1}^{N} \tilde{\theta}^g_{ji}(H)}.100 \tag{4.7}$$

The net spillover from market i to all other markets j could be calculated as the difference from the above two equations:

$$S^g_{i}(H) = S^g_{\bullet i}(H) - S^g_{i\bullet}(H) \tag{4.8}$$

It is worthy to also calculate how much in net terms each market contributes to spillover in other markets. The net pairwise spillovers equation could be presented as follows:

$$S_{ij}^{g}(H) = (\frac{\tilde{\theta}_{ij}^{g}(H)}{\sum_{k=1}^{N} \tilde{\theta}_{ik}^{g}(H)} - \frac{\tilde{\theta}_{ji}^{g}(H)}{\sum_{k=1}^{N} \tilde{\theta}_{jk}^{g}(H)}).100 \tag{4.9}$$

The net pairwise spillover between markets i and j is simply the difference of gross shocks transmitted between market i and j.

In this chapter, we aim to calculate the total spillover indices from the sovereign CDS yields of nine Eurozone countries. The countries have been divided into two groups: core countries, comprising France, Netherlands, Belgium, and Austria, and peripheral countries, comprising Portugal, Spain, Ireland, Italy, and Greece. The model will be replicated three times and applied to each of the nine countries at different times. In the subsequent section, we will provide a detailed analysis of the sample descriptive statistics.

4.4 Descriptive Statistics

The time series dataset analyzed in this study comprises daily frequency data for the sovereign CDS yields of nine European countries, namely Austria, Netherlands, France, Belgium, Greece, Italy, Ireland, Portugal, and Spain, spanning from 15 September 2008 to 30 January 2023. To obtain the growth rates of the sovereign CDS of these countries, the logarithmic difference of the original data was computed. However, it should be noted that data from 2012.3.9 to 2013.9.25 was excluded from our analysis, as Greek CDS temporarily withdrew from the trading market due to the Greek debt crisis and the resulting credit event. Nevertheless, the exclusion of this period is unlikely to affect the overall analysis, as our study is based on three discrete sub-periods models.

Our analysis is divided into three sub-periods. The first data period covers the period from September 15, 2008, the day Lehman Brothers went bankrupt, to March 8, 2012. This period witnessed the GFC and the European sovereign debt crisis. The Greek government's disclosure of its debt crisis at the end of 2009 and contagion rapidly to other Eurozone countries, marked the beginning of the European sovereign debt crisis. The climax of the European debt crisis in the sovereign CDS market occurred in March 2012, when Greece's sovereign CDS yield soared to 37,030.49 basis points and then remained untradable until September 26, 2013. We named this period the crisis period sample, which represents a sample of global and regional economic and financial instability.

The second sub-period, from September 26, 2013, to March 10, 2020, is named the post-crisis period. After the resumption of Greek CDS trading, sovereign CDS yields failed to recover to pre-crisis levels, even though the Troika's bailouts effectively contained the crisis's impact. Sovereign CDS in the Eurozone remained relatively stable during this period, indicating the post-crisis characteristics.

The third sub-period, named the pandemic period, began on March 11, 2020, when the World Health Organization declared COVID-19 a pandemic, and our model runs until the latest available data on January 30, 2023. The pandemic period is marked by the limited economic activity that has affected sovereign credit. Unlike the first sub-period, where the crisis began directly in financial markets, the pandemic period was initiated by the spread of the COVID-19 virus, which had a profound impact on the global economy. While the WHO has not declared the end of the pandemic, the widespread availability of vaccines, the significant decline in deaths, and the reduction in economic activity restrictions indicate that the pandemic period is coming to an end.

Figures C1 to C3 (see in Appendix C) illustrate the alterations in sovereign CDS growth rates for the nine countries across three distinct sub-periods, with Table 4.1 providing a summary statistic description for each phase. Greece stands out with an average value of 0.67%, while the remaining countries hover around 0.3%. Despite Greece having the highest average value, the greatest single-day growth rate was recorded in Austria during the GFC onset, signaling instability in Austria's sovereign credit in response to shocks from the US sub-prime crisis. Concurrently, standard deviations reveal that Austria has the largest value, followed by Greece, indicating that Austria's sovereign credit remained the most unstable among the studied countries throughout the GFC and the European debt crisis, despite being a core country in the Euro area.

As a peripheral nation, Ireland's sovereign credit risk also significantly increased during the GFC period. The considerable rise in Irish sovereign rates can be attributed to factors similar to those of the GFC, including spillover effects and domestic structural instability. On one hand, the Irish economy has enjoyed rapid growth since the mid-1990s but remains susceptible to external shocks from the US due to its peripheral location and small size. On the other hand, Croke (2012) asserts that poor national banking sector regulation and weak EU-level regulation of Ireland's fiscal position greatly exacerbated the Irish fiscal crisis, potentially eroding market confidence in Ireland. Greece, at the center of the European debt crisis, experienced its peak sovereign CDS spreads during that crisis. The line chart reveals that Austria, the Netherlands, and Ireland were most affected by the GFC shock, all exhibiting significant positive growth in 2008. Conversely, Portugal and Greece were most impacted by the European debt crisis in the initial phase, with Greece persisting as the fastest rising risk later on.

In the post-crisis period, the mean value of sovereign CDS yields is negative, indicating a decrease in sovereign credit risk for all target countries. Greece remains the most volatile country in terms of maximum, minimum, and standard deviation, with respective values of 18.5%, -9.85%, and 1.33. The line chart displays a notable outlier for Greece in 2015, coinciding with the early election victory of the left-wing, anti-austerity Syriza party, which disrupted over 40 years of two-party rule. The uncertain political climate and economic policies incited a strong investor response in the Greek sovereign CDS market.

During the second sub-period, Portugal's CDS yields were the second highest (excluding Greece) until the fourth quarter of 2017. After experiencing an economic boom in the twentieth century, Portugal faced economic decline and significant public debt, resulting in the loss of the country's investment market perception following the GFC shock. The key event triggering a rapid increase in Portuguese yield rates was Moody's downgrade of its long-term government bond ratings from Ba2 to Baa1, assigning a negative outlook in July 2011. Afonso et al. (2011) identified a bi-directional causality between sovereign credit ratings and CDS rates, with spillover and persistence effects from downgrades explaining the record-high Portuguese rates in January 2012. After Q4 2017, Italian CDS rates became the second highest among the eight countries (excluding Greece).

The swift escalation in Italian sovereign CDS yields can likely be attributed to government reforms, with an inconclusive presidential election reducing investor confidence in the Italian market, sparking a debt market shock that prompted a rapid increase in Italian sovereign CDS yields from 97.17 on May 15 to 247.04 on May 30. Italian sovereign rates have remained elevated and volatile since Q2 2018.

During the pandemic period, the overall CDS growth rate was positive for all seven countries, except Italy and Greece. This indicates a slight increase in CDS yields compared to the post-crisis period, which can be interpreted as a rise in overall sovereign credit risk due to the pandemic shock. Italy and Greece maintained high yields in the latter part of the post-crisis period but demonstrated a moderate downward trend post-2020, even after the pandemic shock. This suggests a continued improvement in sovereign credit for these two countries. The line chart highlights the most significant fluctuations at the onset of the pandemic, with Portugal and Spain experiencing the most pronounced changes. These countries also exhibit the largest standard deviation, signifying that their sovereign credit was the most volatile during the crisis. Interestingly, the consistency of CDS yield growth rate fluctuations during the pandemic does not display the same uniformity across countries as observed during the crisis, which verifies our hypothesis that the spillover effects during the pandemic are weaker than GFC and European debt crisis.

Table 4.1: Summary Statistic Description in Three Sub-periods

First Sub-period	France	Ireland	Netherlands	Spain	Italy	Greece	Austria	Portugal	Belgium
Mean	0.31	0.34	0.26	0.25	0.25	0.67	0.3	0.37	0.27
Median	0.23	0.14	0.11	0.26	0.24	0.47	0.17	0.38	0.3
Maximum	6.75	6.24	8.02	4.7	6.15	8.46	10.55	5.82	5.2
Minimum	-3.49	-3.54	-3.08	-2.9	-2.65	-2.74	-3.62	-3.49	-3.17
Std.Deviation	1.37	1.29	1.43	1.1	1.21	1.59	1.63	1.26	1.3
Skewness	0.91	1.06	1.5	0.18	0.59	1.11	1.75	0.58	0.19
Kurtosis	6.31	5.53	8.17	3.9	4.21	5.9	10.06	5.23	3.9
Second Sub-period									
Mean	-0.08	-0.11	-0.09	-0.1	-0.04	-0.11	-0.06	-0.15	-0.08
Median	-0.1	-0.1	-0.1	-0.12	-0.09	-0.16	-0.1	-0.16	-0.09
Maximum	3.81	2.56	2.27	5.32	7.28	18.5	3.03	6.18	4.85
Minimum	-4.29	-2.23	-2.15	-2.36	-2.63	-9.85	-1.99	-2.53	-2.06
Std.Deviation	0.71	0.58	0.45	0.75	0.84	1.33	0.44	0.8	0.5
Skewness	-0.07	0.57	0.63	1.15	1.81	7.19	0.72	1.07	1.2
Kurtosis	8.5	5.33	7.88	8.24	12.92	105.34	6.56	7.8	11.26
Third Sub-period									
Mean	0.04	0.01	0.08	0.02	-0.01	-0.04	0.07	0.04	0.06
Median	-0.11	-0.05	0	-0.04	-0.06	-0.07	-0.01	-0.07	-0.06
Maximum	7.4	6.81	4.04	9.66	5.99	7.86	5.71	11.1	7.53
Minimum	-2.45	-1.64	-1.04	-2.83	-1.94	-3.6	-1.62	-3.06	-2.32
Std.Deviation	0.98	0.87	0.69	1.15	0.81	1.02	0.9	1.24	1.12
Skewness	2.78	2.91	2.16	3.84	1.98	2.26	2.63	4.32	2.79
Kurtosis	18.11	17.52	9.8	28.91	14.67	20.9	14.67	34.35	16.36

Note: This table contains the statistic description of sovereign credit default swaps yields daily growth rates of nine Eurozone countries in three sub-periods. The first sub-period starts from 15 September 2008 to 8 March 2012. The second sub-period include data from 26 September 2013 to 10 March 2020. The third period starts from 11 March 2020 to 30 January 2023. The statistics are rounded to two decimal places.
Source: RStudio.

4.5 Empirical Findings

4.5.1 The Full Sample Spillover Table

Our models are based on vector autoregressions of order 4 and generalized variance decompositions of 10-day-ahead forecast errors. These models present the spillover among nine sample countries across three periods. The off-diagonal column sums are labeled as the spillover impacts "to" other countries, while the row sums represent spillover "from" other countries[2]. Moreover, the total spillover index appears in the lower right corner of the Table 4.2, which is calculated using Equation 4.8 and expressed as "to minus from" differences. Overall, own-country CDS yields spillovers account for a high share of forecast error variance in all three panels, as the diagonal values are higher than the off-diagonals.

The total spillover (non-directional) index, which effectively distills various directional growth rate spillovers into a single index, suggests that, on average, 76.98% of the return forecast error variance during the first crisis period comes from spillovers, while 64.38% is observed for all three periods. These periods represent a high total spillover index, indicating apparent contagion effects among the sample countries. The highest contagion effects appear during the GFC and European debt crisis periods, while the post-crisis period exhibits the least spillover effects. The index during the COVID-19 pandemic is higher than the post-crisis but lower than the first sub-period. The results of the total spillover index demonstrate that the sample countries become more interconnected under economic and financial turmoil in the sovereign risk market. However, the connectedness appears weaker during the pandemic than during the GFC and sovereign debt crisis.

Specifically, the "directional to others" row reveals that Spain, France, and Bel-

[2]For example, in the first sub-period, France receives 79.08 spillover effects from other countries, and transmit 93.42 to other countries. Therefore, the net directional connectedness is 93.42 - 79.08 = 14.34.

gium are the dominant transmitters in the crisis period. The "from" column shows that the spillover effects received by the sample countries do not vary much (ranging from 75 to 82) except for Greece (62.49). At the same time, Greece transfers the least contagion risk to other countries (52.35), making it relatively isolated from the sovereign risk market, which might due to the rather inflated volatility in this period. In the post-crisis period, the difference between Greece and other countries becomes more significant, with Greece's sovereign CDS only affecting other countries at a low level (8.8) and receiving the least impact from others (21.05). This condition changes in the third model, where Italy becomes the least affected country (59.34), while it affects other countries the most (105.77). From the outputs of the crisis and post-crisis models, the boundary of spillover effects between peripheral and core countries is unclear.

During the GFC and Eurozone debt crisis, the boundaries between peripheral and core countries were clear as noted in previous literature, but except for Spain. This framework continued into the post-crisis period but did not include Greece, likely due to its slow recovery from the European debt crisis. Investors generally perceive Greek CDS yield volatility as less impactful on other Eurozone countries than during the crisis, resulting in Greece's isolated position in the post-crisis era. Simultaneously, we found that Ireland was closer to the core countries in the sovereign CDS market during the pandemic. This may be because Ireland's excess state debt had been a focus for investors during the GFC and European debt crisis, leading to a lack of stability in Irish sovereign credit. Ireland's economic fundamentals have recovered well since the first crisis period, providing investors with sufficient confidence to maintain sovereign CDS rate stability, like other core countries. This phenomenon also represents the fact that the composition of core and peripheral countries has not always been consistent across different crises.

Table 4.2: Total Spillover Indices Table

First Sub-period	France	Ireland	Netherlands	Spain	Italy	Greece	Austria	Portugal	Belgium	FROM
France	20.92	9.38	13.3	11.34	7.6	5.7	12.79	6.43	12.53	79.08
Ireland	9.45	24.17	9.32	10.18	7.84	7.75	10.3	8.94	12.06	75.83
Netherlands	14.14	10.12	22.99	8.65	7.23	5	13.88	5.67	12.32	77.01
Spain	11.47	8.64	7.96	21.01	11.05	7.55	9.19	11.02	12.12	78.99
Italy	10.89	10.18	8.23	15.62	17.97	6.31	9.86	9.9	11.05	82.03
Greece	9.63	8.13	5.3	10.59	6.37	37.51	7.24	7.74	7.49	62.49
Austria	14.92	9.78	13.36	10.86	7.05	5.48	21.35	5.09	12.09	78.65
Portugal	9.38	11.4	5.52	14.85	9.07	8.38	8.91	22.76	9.73	77.24
Belgium	13.54	8.54	12.89	12.91	9.3	6.19	11.26	6.91	18.46	81.54
Directional TO Others	93.42	76.16	75.88	95	65.52	52.35	83.43	61.71	89.4	692.86
Directional Inlcuding Own	114.34	100.33	98.86	116.01	83.48	89.86	104.78	84.47	107.86	TCI
NET Directional Connectedness	14.34	0.33	-1.14	16.01	-16.52	-10.14	4.78	-15.53	7.86	76.98
Second Sub-period	France	Ireland	Netherlands	Spain	Italy	Greece	Austria	Portugal	Belgium	FROM
France	28.24	11.36	4.36	12.88	12.78	0.91	5.25	11.49	12.72	71.76
Ireland	7.79	28.42	4.61	13.02	13.59	0.89	4.56	16.29	10.84	71.58
Netherlands	6.91	11.76	33.41	7.16	8.3	0.77	9.25	10.67	11.78	66.59
Spain	6.06	8.63	3.29	29.2	18.66	0.86	3.32	21.39	8.6	70.8
Italy	5.08	8.53	2.09	23.13	31.45	0.86	2.66	20.15	6.05	68.55
Greece	1.29	2.4	0.84	3.5	4.41	78.95	0.46	5.4	2.75	21.05
Austria	6.4	10.71	8.68	10.01	10.94	1.03	28.92	10.92	12.4	71.08
Portugal	5.36	7.9	2.62	18.8	17.84	1.86	2.68	34.69	8.26	65.31
Belgium	10.84	9.9	5.32	12.35	11.55	1.63	8.05	13.03	27.35	72.65
Directional TO Others	49.72	71.18	31.81	100.85	98.06	8.8	36.23	109.33	73.39	579.38
Directional Inlcuding Own	77.97	99.6	65.22	130.05	129.52	87.75	65.14	144.02	100.74	TCI
NET Directional Connectedness	-22.03	-0.4	-34.78	30.05	29.52	-12.25	-34.86	44.02	0.74	64.38
Third Sub-period	France	Ireland	Netherlands	Spain	Italy	Greece	Austria	Portugal	Belgium	FROM
France	28.56	10.6	4.44	9.09	12.43	6.97	7.93	8.99	10.99	71.44
Ireland	14.82	27.57	4.41	8.15	8.13	4.5	6.28	10.08	16.07	72.43
Netherlands	11.17	13.11	26.71	5.37	5.04	3.65	16.44	5.94	12.56	73.29
Spain	5.33	4.93	3.21	25.62	22.92	6.73	3.03	24.18	4.05	74.38
Italy	4.32	3.57	4.29	19.36	40.66	6.29	1.93	17.03	2.56	59.34
Greece	4.33	2.66	3.16	14.36	22.08	32.89	2.48	15.2	2.83	67.11
Austria	13.19	14.56	10.1	5.17	4.12	3.85	27.18	5.7	16.14	72.82
Portugal	5.1	4.05	3.44	22.98	23.58	7.95	2.25	27.07	3.57	72.93
Belgium	14.82	17.52	5.63	6.75	7.47	5.12	8.55	6.35	27.8	72.2
Directional TO Others	73.07	70.99	38.68	91.24	105.77	45.06	48.89	93.47	68.78	635.95
Directional Inlcuding Own	101.63	98.56	65.39	116.86	146.43	77.95	76.06	120.55	96.58	TCI
NET Directional Connectedness	1.63	-1.44	-34.61	16.86	46.43	-22.05	-23.94	20.55	-3.42	70.66

Note: This table contains the total spillover indices of sovereign credit default swaps yields daily growth rates of nine Eurozone countries in three sub-periods. The first sub-period starts from 15 September 2008 to 8 March 2012. The second sub-period include data from 26 September 2013 to 10 March 2020. The third period starts from 11 March 2020 to 30 January 2023. The off-diagonal column sums are labeled as the spillover impacts "to" other countries, and the row sums are "from" other countries. The data of net directional connectedness come from "to minus from" differences.The total spillover index (TCI - total connectedness index) appears in the lower right corner of the table. The results are rounded to two decimal places.
Source: RStudio.

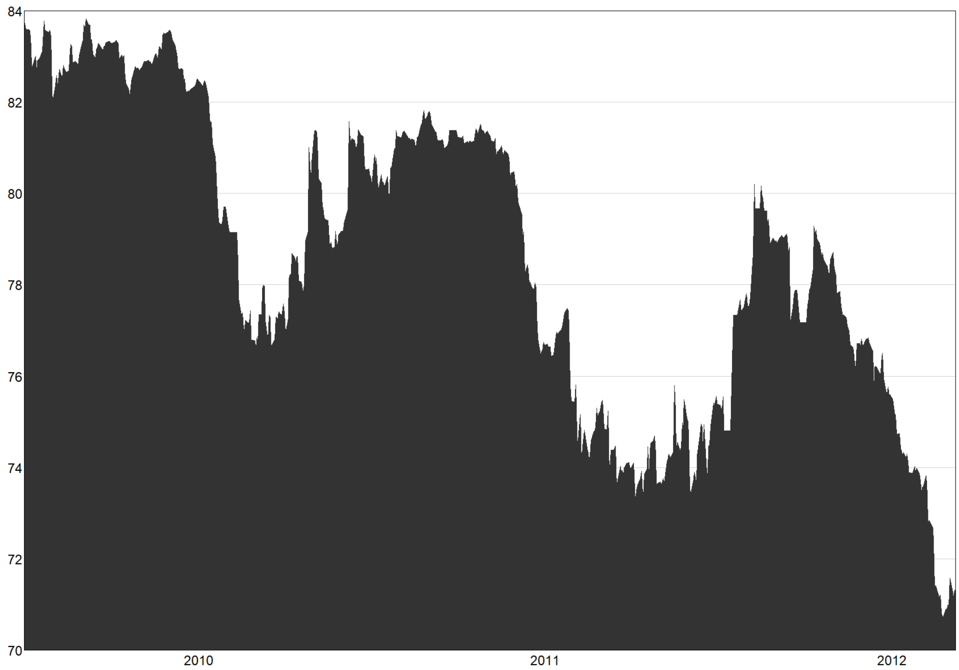
4.5.2 Time-varying Total Spillover Index

Figures 4.1 to 4.3 present the time-varying total spillover index obtained from 200 days of rolling window estimation. It is evident that the spillover index remains high from the third quarter of 2009 to the end of the year. A valley appears in early 2010 but increases in the second quarter. At the beginning of 2010, various policy measures were implemented to address the debt crisis, resulting in a stabilization of market sentiment and a moderation of the sovereign market spillover effect. In April 2010, Standard and Poor's downgraded Greece's debt ratings below investment grade to junk bond status, followed by separate downgrades of the sovereign credit ratings of several peripheral Eurozone countries, leading to a sharp rise in spillover effects. The high spillover level of around 81 persists until the end of 2010 and decreases sharply in the last quarter of 2010, likely due to the impact of the second round of bailouts for Greece. Another valley emerges in the first half of 2011, followed by a local peak in the third quarter of 2011, coinciding with a debt crisis that has not seen significant improvement. The total spillover index decreases to a lower level of around 71 in early 2012.

The overall trend of the spillover index in the second period is lower than that of the first model, with the highest level being less than 77 and the lowest approximately 50. There are significant decreases in the first quarter of 2015, the second quarter of 2017, the first quarter of 2018, and early 2020. The time-varying spillover under the pandemic is observed to reach the lowest level of the period in the first quarter of 2022. In conjunction with Table 4.2., it can be seen that the total spillover index in the third sub-period is 70.66, while the graph is generated due to the use of the 200-day rolling window estimation method, starting at the end of 2020 and presenting a mean value of less than 70. This indicates that the high overall spillover effect during the pandemic is only present in 2020, the first year of the pandemic. After 2021, the sovereign market spillovers begin to return to their pre-pandemic state.

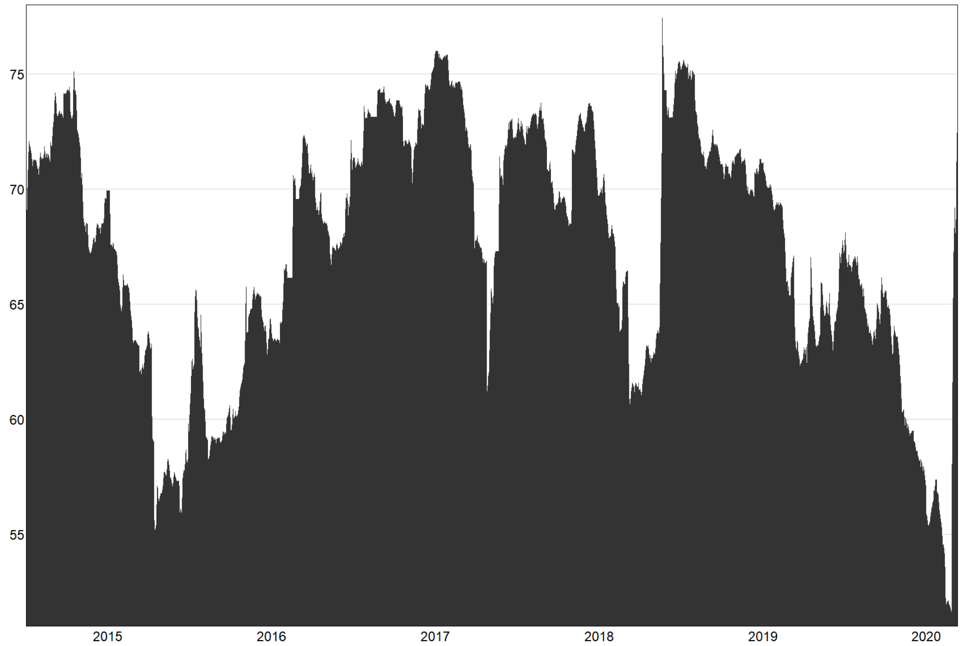
To examine the sensitivity of the results, we alter the order of the VAR. The spillover index for orders 2 through 6 are calculated, and the minimum and maximum values are assessed. The outputs demonstrate that the total spillover plot is not sensitive to the choice of the order of VAR.

Figure 4.1: Time-varying Total Spillover Index - Crisis Period



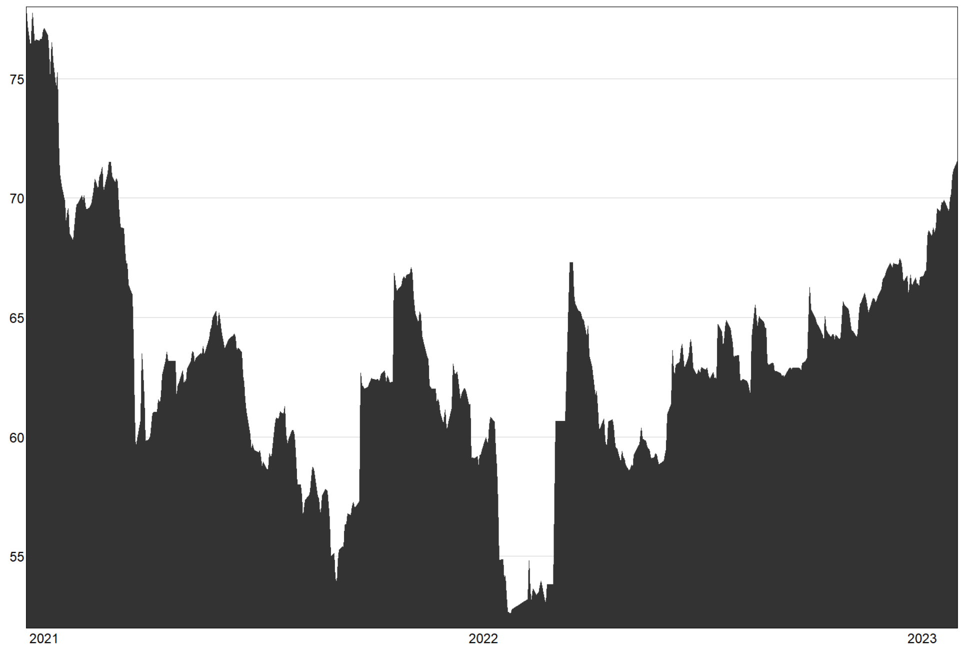
Note: The crisis period starts from 15 September 2008 to 8 March 2012. This figure presents the time-varying total spillover index from France, Austria, Netherlands, Belgium, Greece, Italy, Ireland, Spain and Portugal. The plots are obtained from 200 days of rolling window estimation. *Source:* RStudio.

Figure 4.2: Time-varying Total Spillover Index - Post-crisis Period



Note: The post-crisis period starts from 26 September 2013 to 10 March 2020. This figure presents the time-varying total spillover index from France, Austria, Netherlands, Belgium, Greece, Italy, Ireland, Spain and Portugal. The plots are obtained from 200 days of rolling window estimation.
Source: RStudio.

Figure 4.3: Time-varying Total Spillover Index - Pandemic Period



Note: The pandemic period starts from 11 March 2020 to 30 January 2023. This figure presents the time-varying total spillover index from France, Austria, Netherlands, Belgium, Greece, Italy, Ireland, Spain and Portugal. The plots are obtained from 200 days of rolling window estimation.
Source: RStudio.

4.5.3 Rolling-sample Gross and Net Directional Spillover Plots

Our models' outputs display the time-varying gross and net directional spillover indices obtained from rolling window estimation. The net directional spillover plots are derived from the difference between the gross directional spillover to others and from others plots. Information is contained in the "Directional TO Others" row (the sum of which is given by $S^{g}_{\bullet i}(H)$ in Equation 4.7) and the "Directional FROM Others" column (the sum of which is given by $S^{g}_{i\bullet}(H)$ in Equation 4.6). We also calculate net pairwise spillovers between two countries, and the plots are shown in Figures 4.7, 4.11, and 4.15.

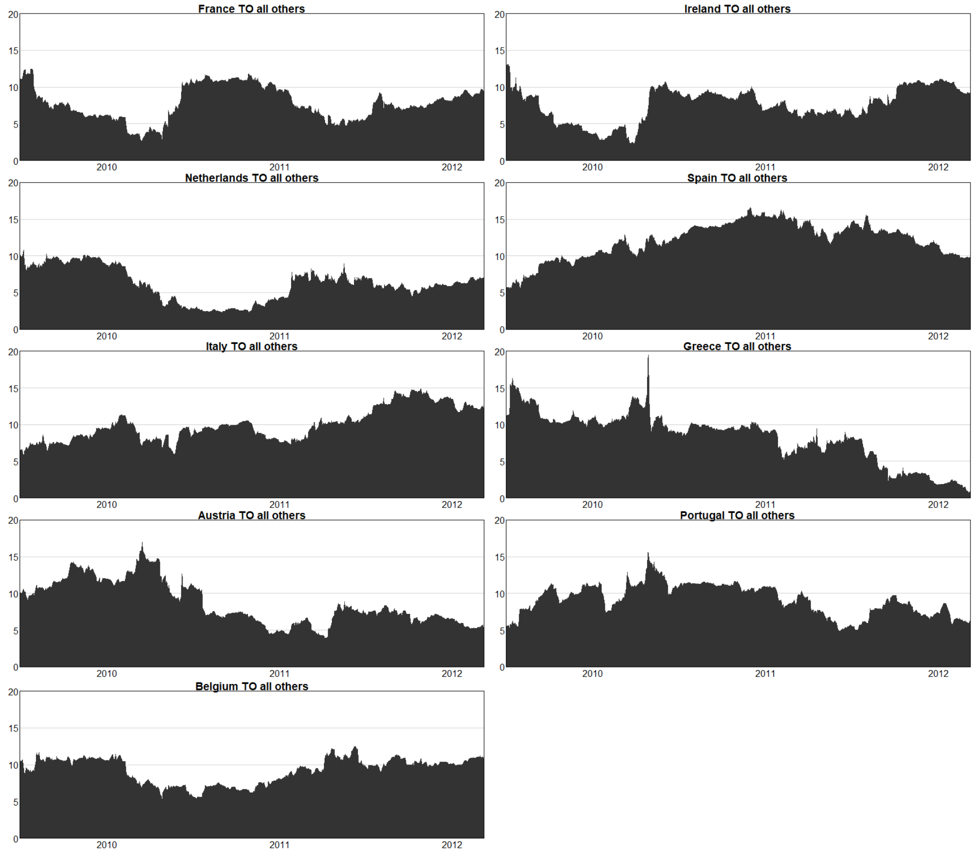
In the first subperiod, as seen in Figures 4.4 and 4.5, fluctuations in the level of outward spillovers are, on average, stronger than those received by individual countries. In particular, outward spillovers can reach a maximum level of 19%, as was the case for Greece in the second quarter of 2010. Received spillovers, on the other hand, are largely below 10%. In the second quarter of 2010, spillovers from France, Ireland, Italy, Greece, Austria, and Portugal to other countries all increased significantly (Figure 4.4). Both Greece sovereign bonds and CDS rates were high, and the credit ratings of the three major rating agencies were downgraded in April 2010. Simultaneously, Standard & Poor's downgraded the sovereign ratings of Spain and Portugal. Figure 4.6 reveals that Greece, Spain, Portugal, and France were the main risk spillover transmitters during this period, while the other countries received more risk. Figure 4.7 shows the results of net pairwise spillovers, which indicates the specific path of spillover effects among countries in this phase. Firstly, the spillover effect on Greece was significant for all eight other countries in April 2010. However, France, Spain, and Portugal did not continue to receive spillovers from Greece until the third quarter; instead, these three countries had a greater impact on Greece. Examining France during this period, we can see that France was the spillover effects transmitter for all countries except Spain. Portugal's risk spillover at this time mainly came from France and Spain. Spain, on the other hand, was a dominant net spillover transmitter for all other countries in the second and third quarters of 2010. In summary, we can see that even though the sharp downgrade of Greece's sovereign rating by the rating agencies in April 2010 led to sharp shocks in the sovereign CDS of the Eurozone countries, it was Spain that had the most significant spillover to the Eurozone sovereign market in the following months. Of the three countries subject to this sovereign rating downgrade, the largest economy was Spain. The spillover effect from Spain reflects the market's concern about the contagion of the sovereign debt crisis. France, on the other hand, was the second-largest spillover country in this period due to the contagion of the debt crisis and the impact of its status as a core Eurozone country.

In the second sub-period, Figure 4.2 displays a high point of spillovers in mid-2018, and Figure 4.8 reveals a local high point for all countries during this period. The distinction lies in the fact that core countries maintain lower spillovers afterward, while peripheral countries, excluding Greece, exhibit an upward trend in spillovers. Figure 4.10 shows that core countries predominantly receive sovereign CDS spillovers, while peripheral countries, apart from Greece and Ireland, primarily serve as transimitters, particularly after mid-2018. In August 2018, Greece accepted its final loan from European creditors, concluding a bailout program initiated in 2015. To finance the debt owed to the EU and IMF, Greece government commits to a long-term recovery policy that is unique compared to other marginal countries, resulting in limited spillover effects. Meanwhile, our results indicate that Ireland no longer displays marginal country status in the sovereign credit market beyond 2018. Based on the net pairwise spillover results (Figure 4.11), Spain and Portugal both act as transmitters to other countries regarding sovereign CDS spillovers since the second half of 2018. Conversely, net spillovers between Spain and Portugal are minimal.

In the third sub-period, Figure 4.3 demonstrates that the overall spillover effect peaks at the end of 2020, coinciding with the first winter of the pandemic. The transmission data for each country (Our World in Data, 2023) reveals a significant increase in daily infections at the onset of winter 2020. As seen in Figure 4.12, Italy is the most critical transmitter of sovereign CDS spillover effects at the end of 2020, with over 15%. Spain follows with more than 12%, and Portugal emerges as the primary transmitter in early 2021, also surpassing 15%. Examining the net spillover plots (Figure 4.14), these three countries remain significant transmitters at the end of 2020 and the beginning of 2021. Furthermore, Figure 4.15 shows that Italy transmits positive spillover effects to all countries at the end of 2020. Additionally, core countries primarily act as receivers of sovereign credit spillovers. Notably, Greece is the main transmitter in winter 21/22. Pairwise spillover plots reveal that the spillover effect primarily impacts Italy, Spain, and Portugal, with a lesser influence on core countries and Ireland. The question arises: Is the sovereign CDS spillover effect related to direct pandemic data? According to our results, the relationship is not significant. At the beginning of 2022, the highest daily infection rate in the target countries occurred in the Netherlands, which served as the spillover effect transmitter at this time, but only by about 2%. Despite a less severe pandemic in Greece during the same period, the transmission effect is stronger, which suggests market concerns about sovereign risks do not stem from pandemic data.

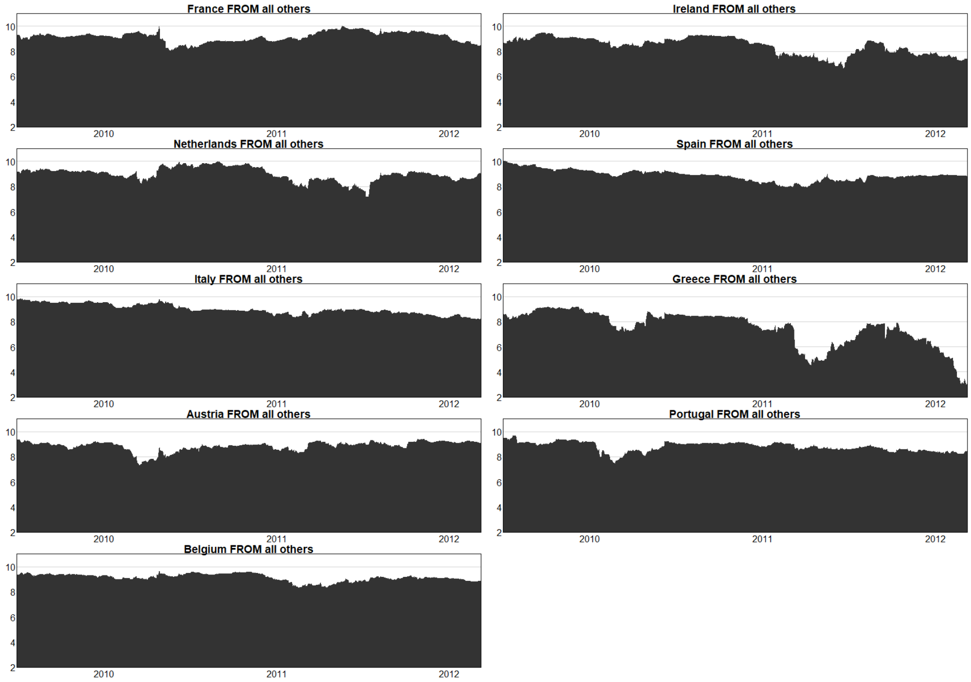
The outcomes of our model underscore the temporal variation of spillover effects resultant from the growth of sovereign CDS in both core and peripheral Eurozone nations. Firstly, the static and dynamic rolling window analyses align with our conjecture that the contagion effects are most pronounced during the initial sub-period, followed by the pandemic's crisis period. Meanwhile, the post-crisis period exhibits the most attenuated contagion effects. Evaluating the interrelationship among international sovereign CDS markets not only deepens our comprehension but also holds significant importance for investors (both domestic and international) participating in the CDS market. Secondly, our results also elucidate the fact that the composition of core and periphery countries hasn't remained consistent throughout different crises. Specifically, during the European Sovereign Debt Crisis, the spillover effects triggered by Greece's debt predicaments permeated the sovereign credit markets of the other eight countries. However, following Greece's re-entry into the sovereign CDS market in 2013, only mild contagion effects have endured among other nations. Given Greece's unique sovereign credit profile, it experiences the least spillover effects within the model, particularly in the second sub-model. The demarcation between core and peripheral nations becomes most explicit when scrutinizing spillover shocks emanating from Greece during the Eurozone Debt Crisis. Nevertheless, in the post-crisis era, Spain's spillover effect associates equivalently with both country groups. Amid the pandemic, spillovers from the four periphery countries became intricately linked, whereas Ireland demonstrated a tighter association with spillovers from the core nations. This segment of the analysis offers international investors and macro policymakers some vital insights into how individual markets respond to other international markets in different phases, thereby informing the modification of their strategies for CDS across diverse nations. Finally, our investigation suggests that Spain and Portugal have functioned as the principal spillover transmitters throughout all three periods, with Italy surfacing as the dominant transmitter amid the pandemic. Greece, being the epicenter of the European Debt Crisis, only exerted a potent spillover effect on other Eurozone nations in the early crisis period. Spain and Portugal, despite being severely impacted, acted as the dominate transmitters of spillover throughout the crisis, likely due to their substantial economic fundamentals. Policymakers can glean from the results of the spillover effect model, for instance, when mitigating the spillover impact of the sovereign CDS market during the European Debt Crisis. By stabilizing the CDS spreads of Spain and Portugal, one can effectively thwart the contagion to the sovereign credit markets of other Eurozone nations.

Figure 4.4: Directional Spillovers of Sovereign CDS Growth Rate to Nine Countries - First Sub-period



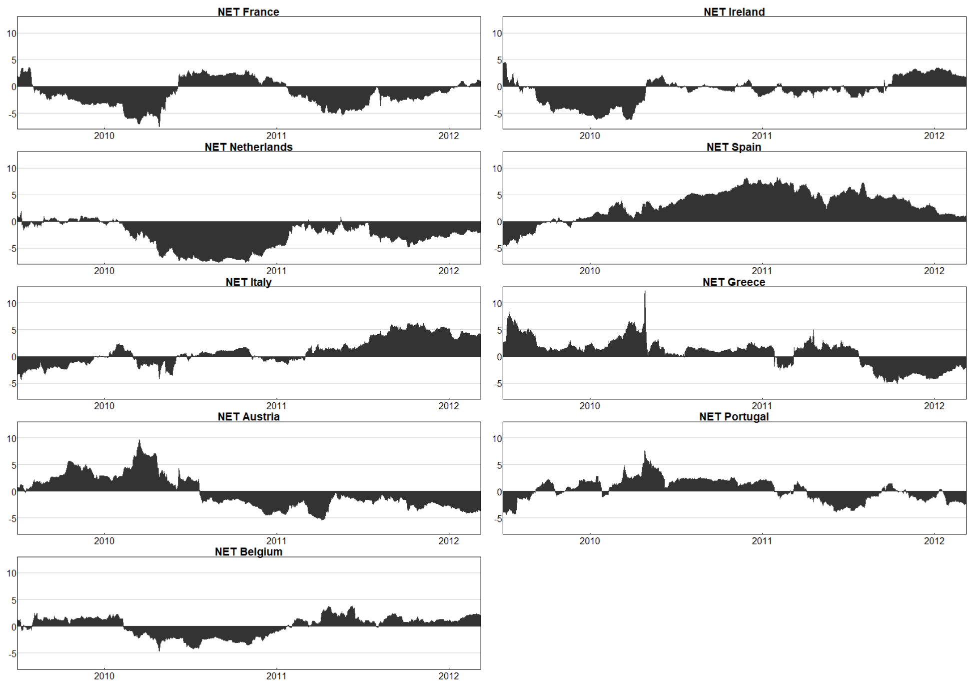
Note: The outputs are obtained through 200 days of rolling window estimation. The first sub-period starts from 15 September 2008 to 8 March 2012.
Source: RStudio.

Figure 4.5: Directional Spillovers of Sovereign CDS Growth Rate from Nine Countries - First Sub-period



Note: The outputs are obtained through 200 days of rolling window estimation. The first sub-period starts from 15 September 2008 to 8 March 2012.
Source: RStudio.

Figure 4.6: Net Directional Spillovers of Sovereign CDS Growth Rate of Nine Countries - First Sub-period



Note: The outputs are obtained through 200 days of rolling window estimation. The first sub-period starts from 15 September 2008 to 8 March 2012.
Source: RStudio.

Figure 4.7: Net Pairwise Spillovers of Sovereign CDS Growth Rate of Nine Countries - First Sub-period

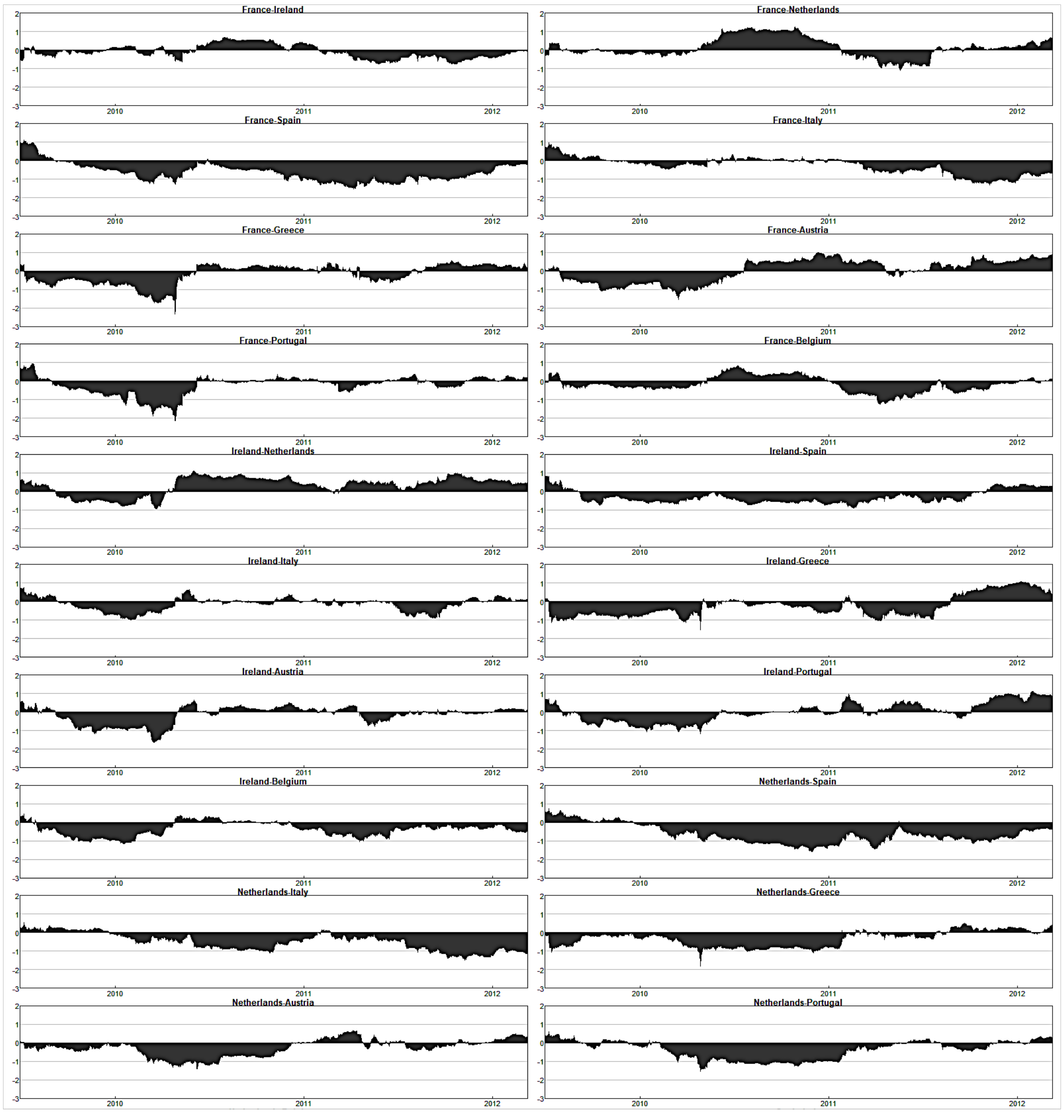
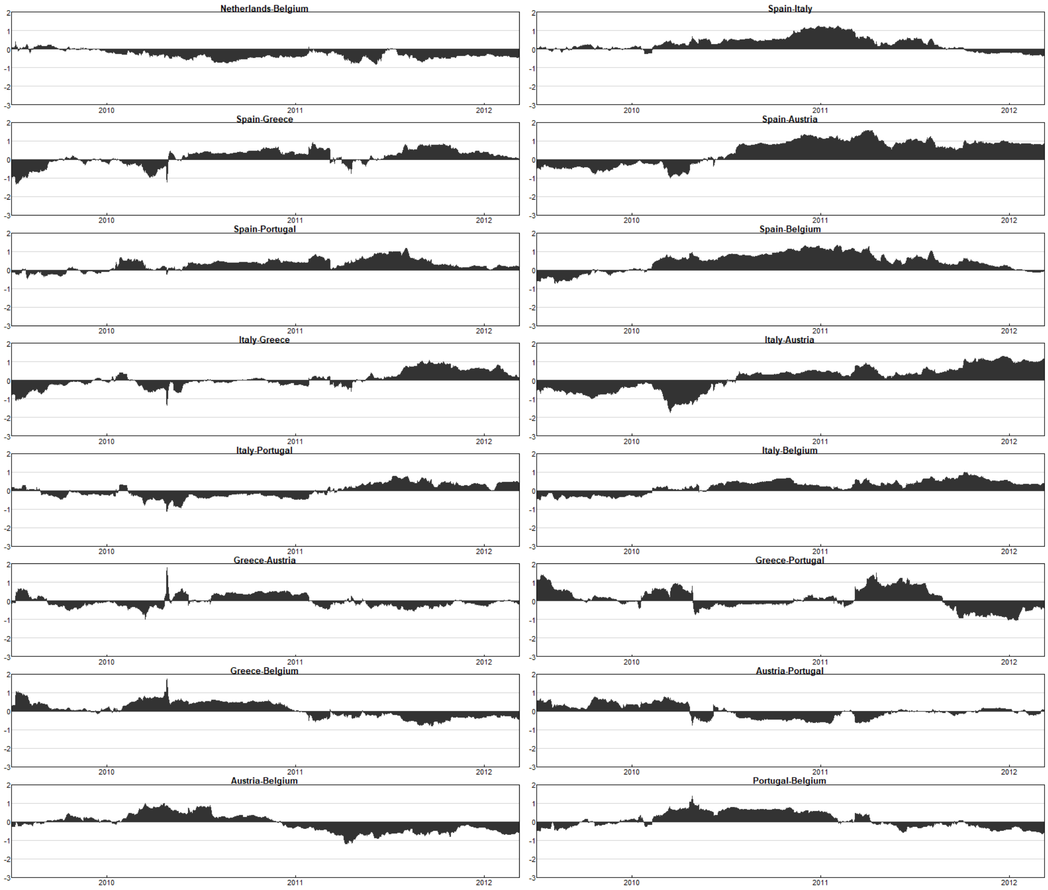
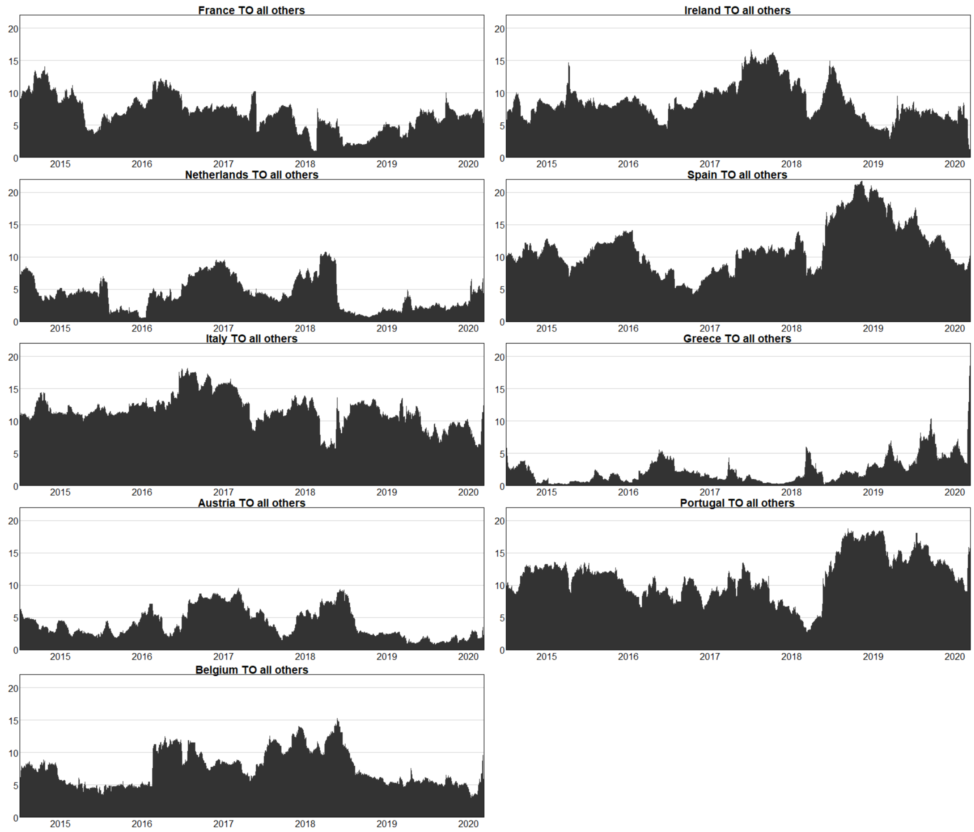


Figure 4.7: (continued)



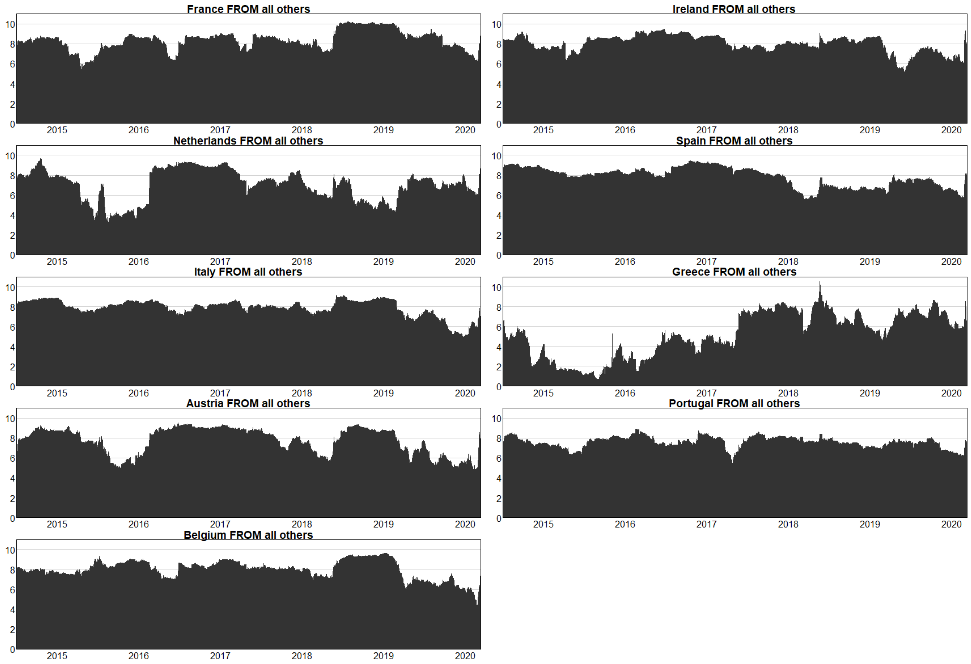
Note: The outputs are obtained through 200 days of rolling window estimation. The first sub-period starts from 15 September 2008 to 8 March 2012.
Source: RStudio.

Figure 4.8: Directional Spillovers of Sovereign CDS Growth Rate to Nine Countries - Second Sub-period



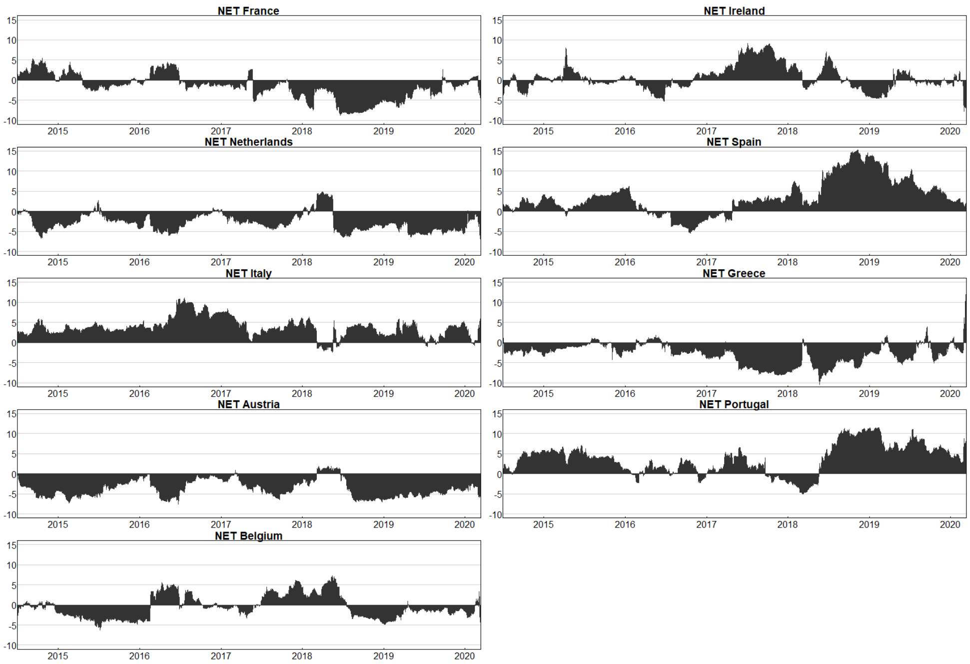
Note: The outputs are obtained through 200 days of rolling window estimation. The second sub-period include data from 26 September 2013 to 10 March 2020.
Source: RStudio.

Figure 4.9: Directional Spillovers of Sovereign CDS Growth Rate from Nine Countries - Second Sub-period



Note: The outputs are obtained through 200 days of rolling window estimation. The second sub-period include data from 26 September 2013 to 10 March 2020.
Source: RStudio.

Figure 4.10: Net Directional Spillovers of Sovereign CDS Growth Rate of Nine Countries - Second Sub-period



Note: The outputs are obtained through 200 days of rolling window estimation. The second sub-period include data from 26 September 2013 to 10 March 2020.
Source: RStudio.

Figure 4.11: Net Pairwise Spillovers of Sovereign CDS Growth Rate of Nine Countries - Second Sub-period

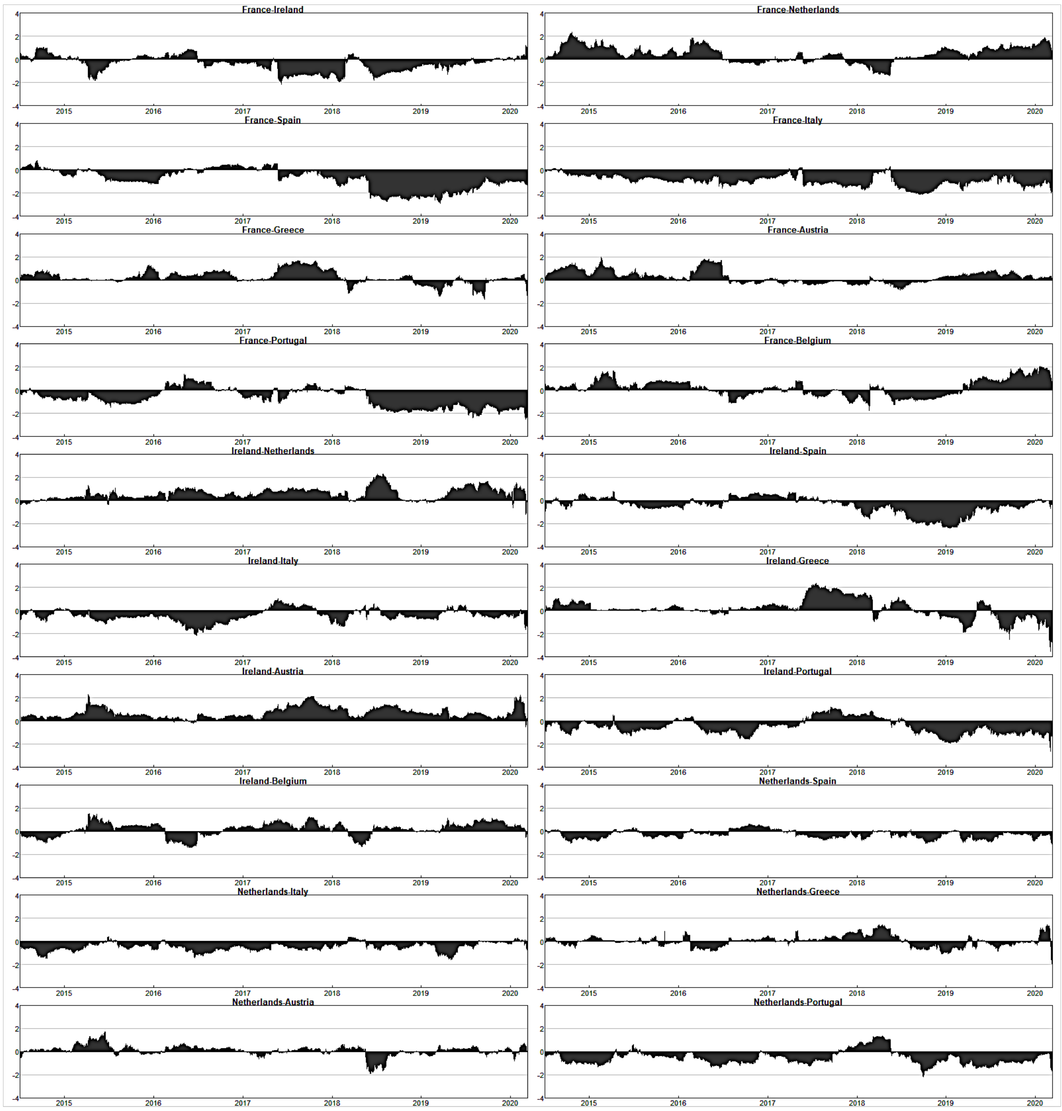
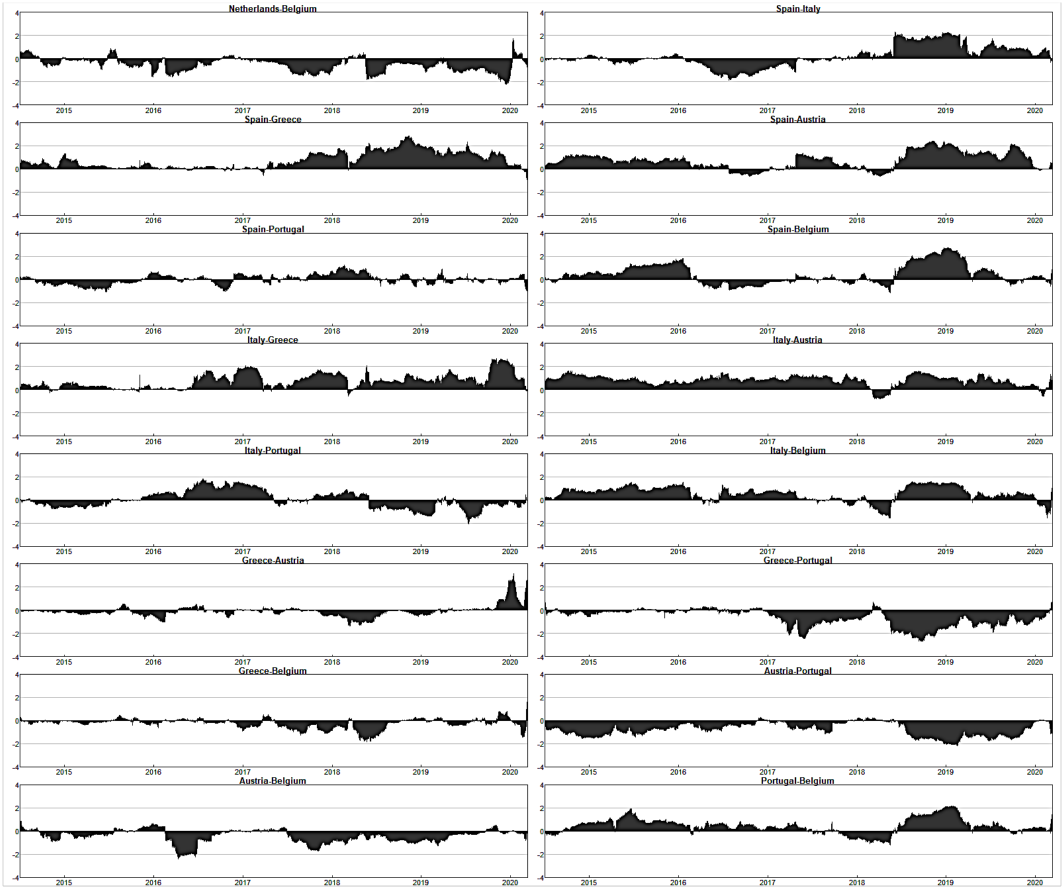
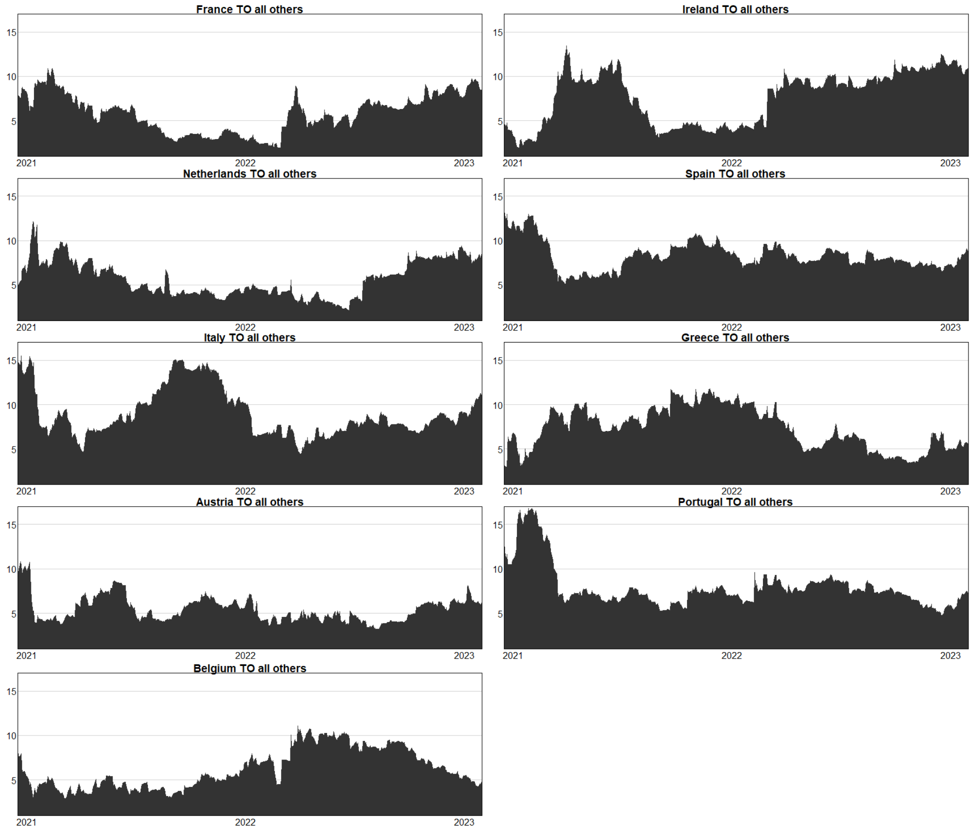


Figure 4.11: (continued)



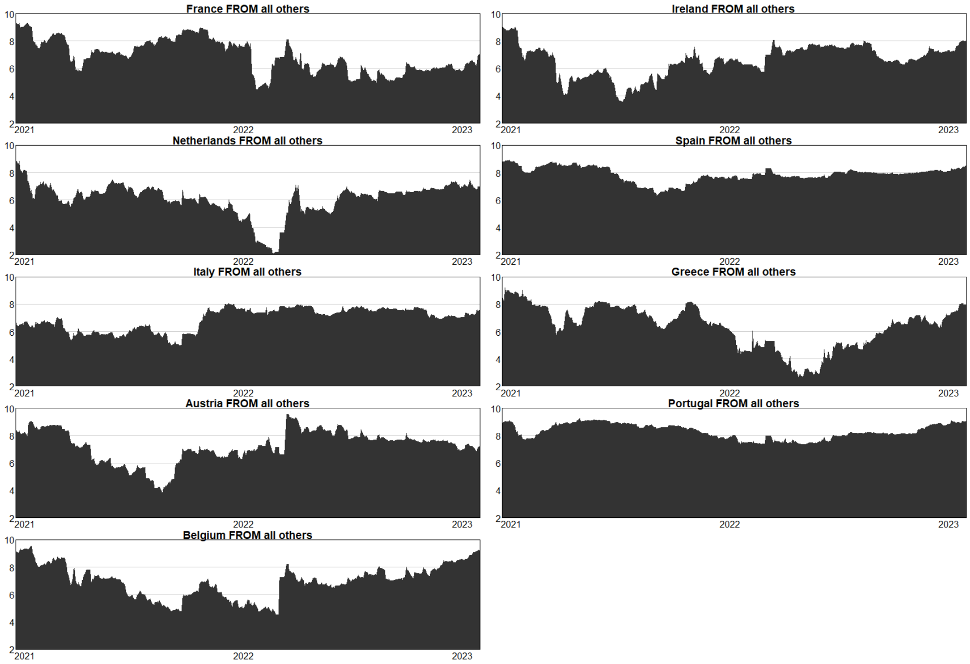
Note: The outputs are obtained through 200 days of rolling window estimation. The second sub-period include data from 26 September 2013 to 10 March 2020.
Source: RStudio.

Figure 4.12: Directional Spillovers of Sovereign CDS Growth Rate to Nine Countries - Third Sub-period



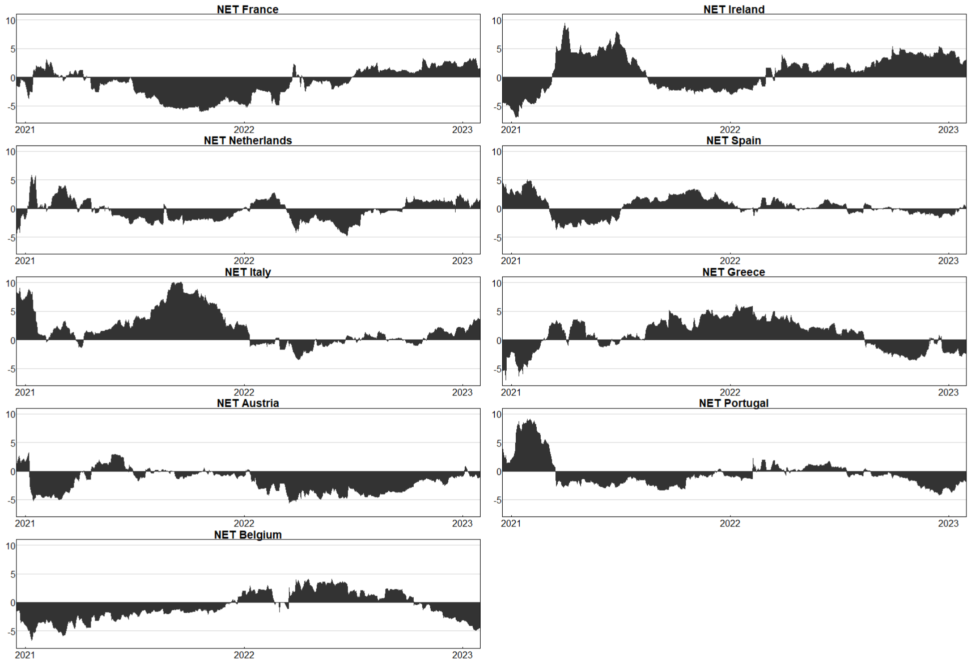
Note: The outputs are obtained through 200 days of rolling window estimation. The third period starts from 11 March 2020 to 30 January 2023.
Source: RStudio.

Figure 4.13: Directional Spillovers of Sovereign CDS Growth Rate from Nine Countries - Third Sub-period



Note: The outputs are obtained through 200 days of rolling window estimation. The third period starts from 11 March 2020 to 30 January 2023.
Source: RStudio.

Figure 4.14: Net Directional Spillovers of Sovereign CDS Growth Rate of Nine Countries - Third Sub-period



Note: The outputs are obtained through 200 days of rolling window estimation. The third period starts from 11 March 2020 to 30 January 2023.
Source: RStudio.

Figure 4.15: Net Pairwise Spillovers of Sovereign CDS Growth Rate of Nine Countries - Third Sub-period

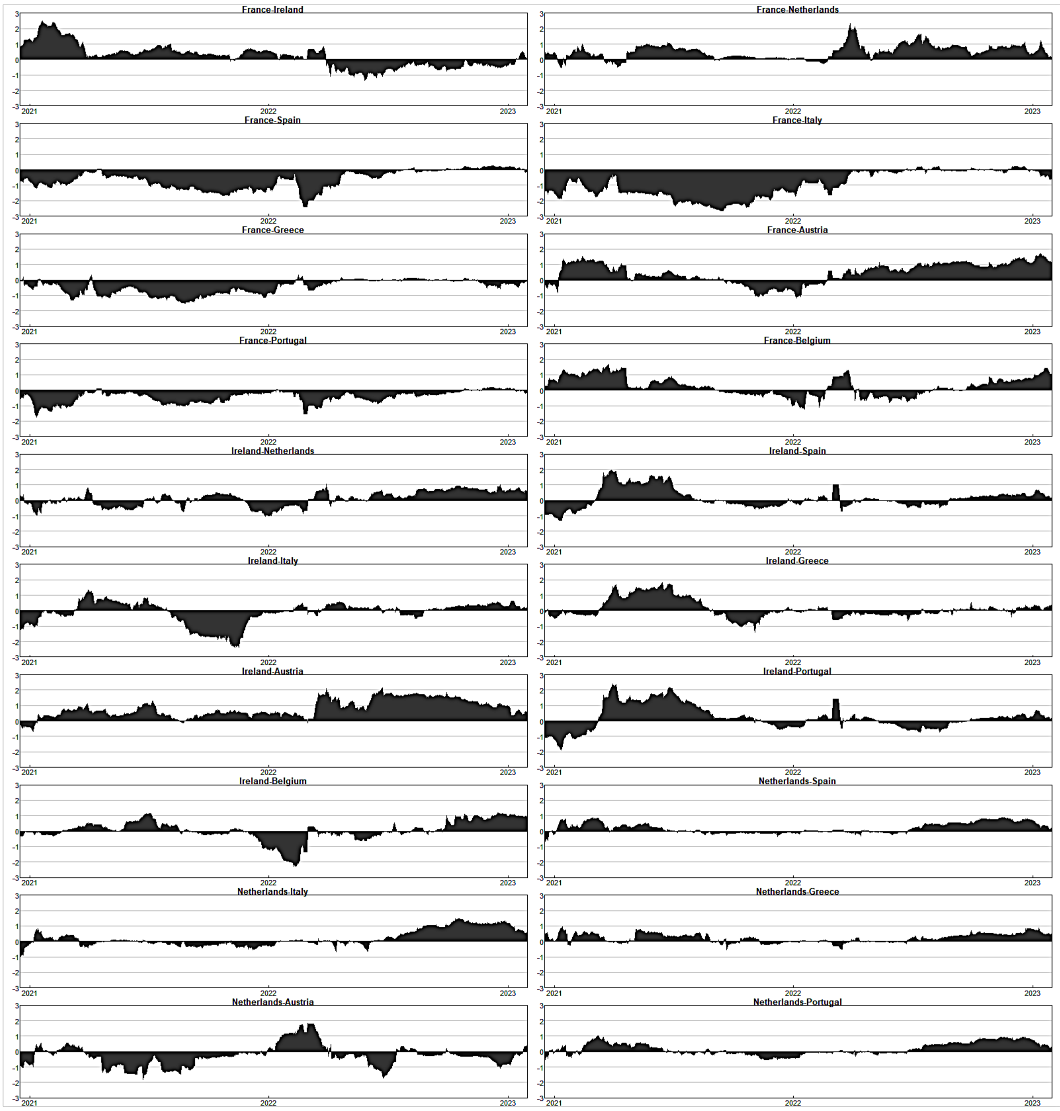
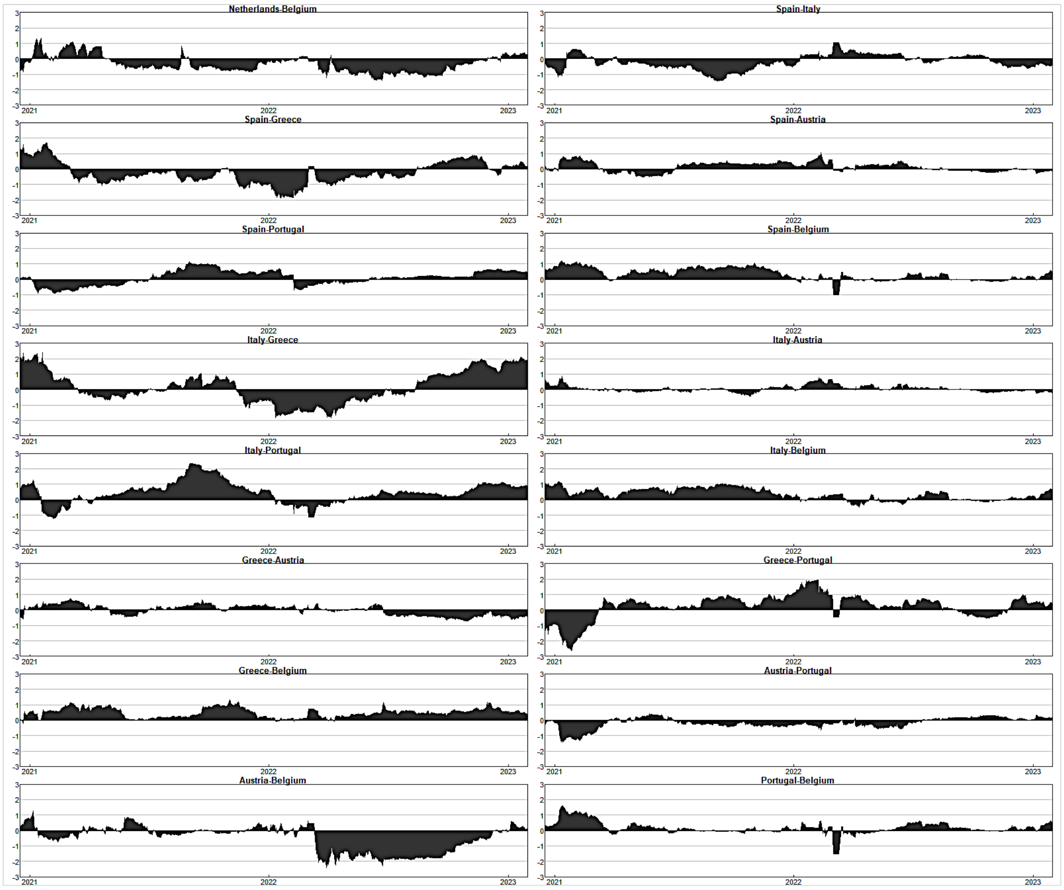


Figure 4.15: (continued)



Note: The outputs are obtained through 200 days of rolling window estimation. The third period starts from 11 March 2020 to 30 January 2023.
Source: RStudio.

4.6 Conclusion

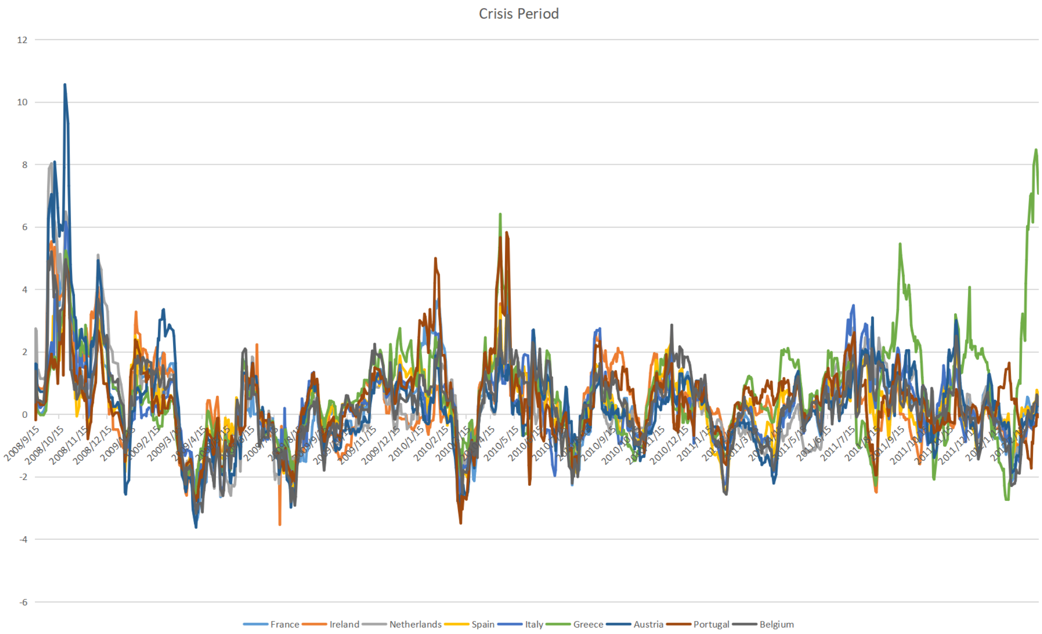
In this chapter, we have broadened the existing literature by exploring the dynamic connectedness between Eurozone core and periphery countries' sovereign CDS markets. We employed the Diebold and Yilmaz (2012) spillover effects index, based on the VAR model, to analyze changes in sovereign CDS in the euro area from the GFC and European sovereign debt crisis period up to the end of the COVID-19 pandemic. This study addressed a discernible gap in the comprehension of spillover effects in sovereign credit markets during the post-crisis phase and throughout the pandemic. Even though the sovereign CDS markets of the Eurozone correlated more tightly during stress periods than in ordinary times, we have discovered that spillovers exhibit differing behavior across various stress environments. They showed stronger interconnections between individual sovereigns during the GFC and the Eurozone Debt Crisis compared to the pandemic period. Furthermore, we have identified temporally varying spillover effects, with countries such as France, Greece, and Italy demonstrating significant variations over time. Notably, Spain and Portugal emerged as the dominate transmitters of spillover effects over the long term amongst the nine Eurozone target countries. This revelation underscored the stable dominant transmitter roles these peripheral nations occupy in the sovereign market, suggesting a high likelihood of them transmitting sovereign spillover risks to other Eurozone nations in the future.

Our findings offered valuable insights for market participants. For instance, relationships among the Eurozone sovereign CDS markets were highly sensitive to crises. This feature should be referred to in investment or policy decisions depending on the characteristics of the crisis - the GFC, European debt crisis and the COVID-19 pandemic. Moreover, our empirical results suggested that the nine sovereign CDS markets that deliver shocks to each other change over time. Consequently, investors and policymakers should attentively consider these dynamic linkages in their decision-making process according to investment horizons or their policies. Both static and dynamic models underscored Spain and Portugal as dominant transmitters from the GFC through the COVID-19 pandemic. Therefore, market participants should adequately respond to crises by recognizing the roles of Spain and Portugal as transmitters. Depending on the spillover results, portfolio managers or individual investors could devise strategies to circumvent contagion risk during crises by computing dynamic hedge ratios or optimal portfolio weights. Similarly, policymakers should attend to the dynamic linkages of dominate transmitters or receivers to curtail contagion risks arising from the interdependence of sovereign CDS markets.

Future research could expand the analysis beyond the Eurozone to explore the contagion effects of sovereign CDS on a global scale. Another intriguing area for investigation would be to examine the spillover effects between sovereign credit markets and other financial markets, such as equity and foreign exchange markets. This would furnish an alternate perspective for investors and further enhance our understanding of the intricate relationships within financial markets.

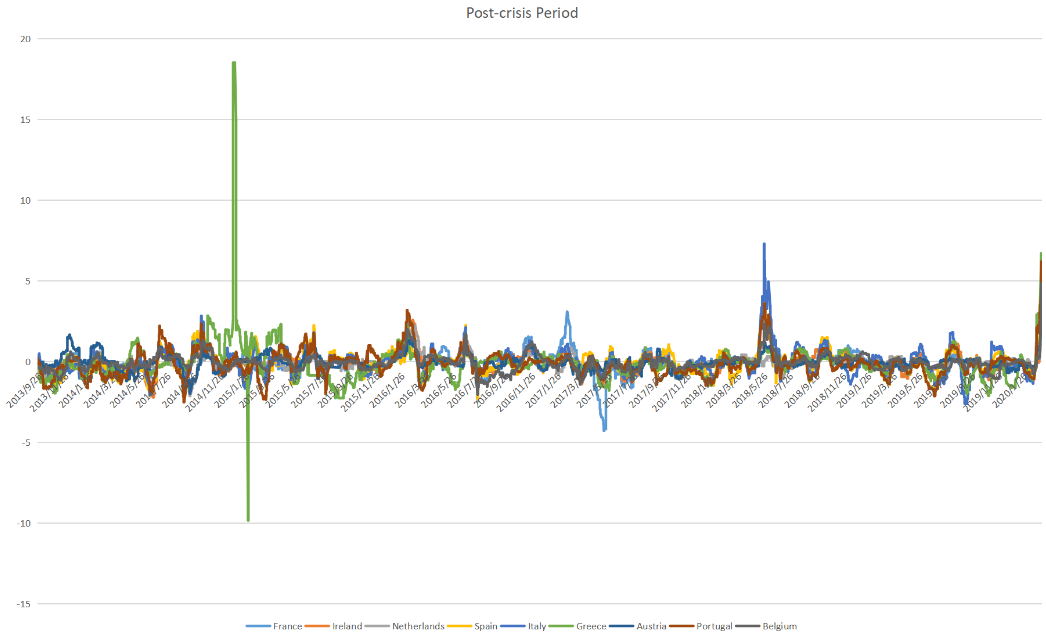
4.7 Appendix C

Figure C1: Sovereign Credit Default Swaps Growth Rate in Crisis Periods



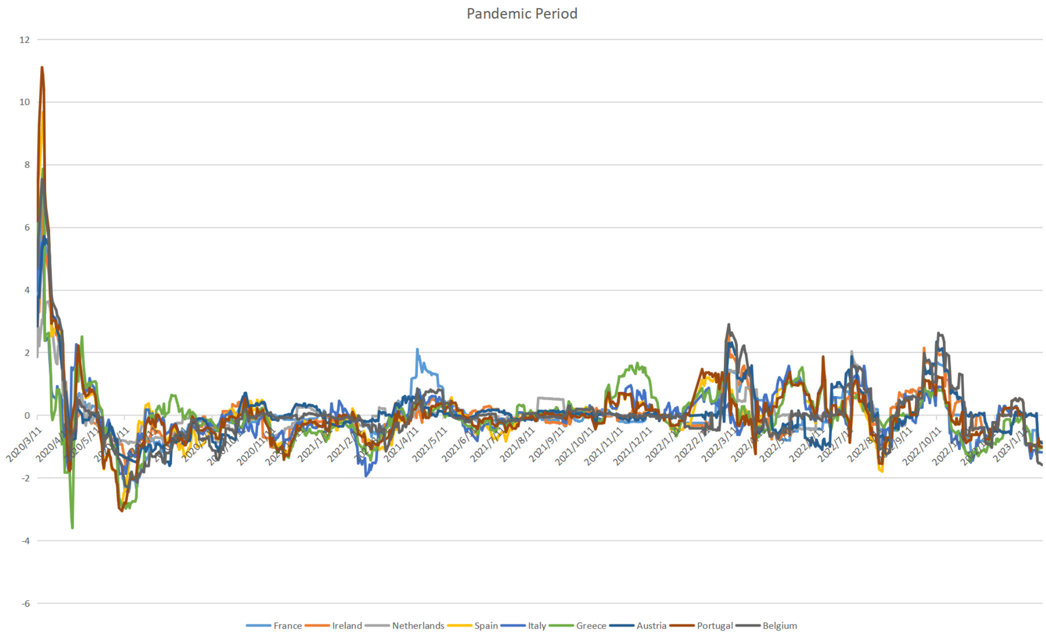
Note: This figure presents the line chart of nine countries' sovereign credit default swaps yields daily growth rates. The crisis period starts from 15 September 2008 to 8 March 2012. The growth rates are measured as percentage (%).
Source: Thomson Reuters Datastream and self-calculation.

Figure C2: Sovereign Credit Default Swaps Growth Rate in Post-crisis Periods



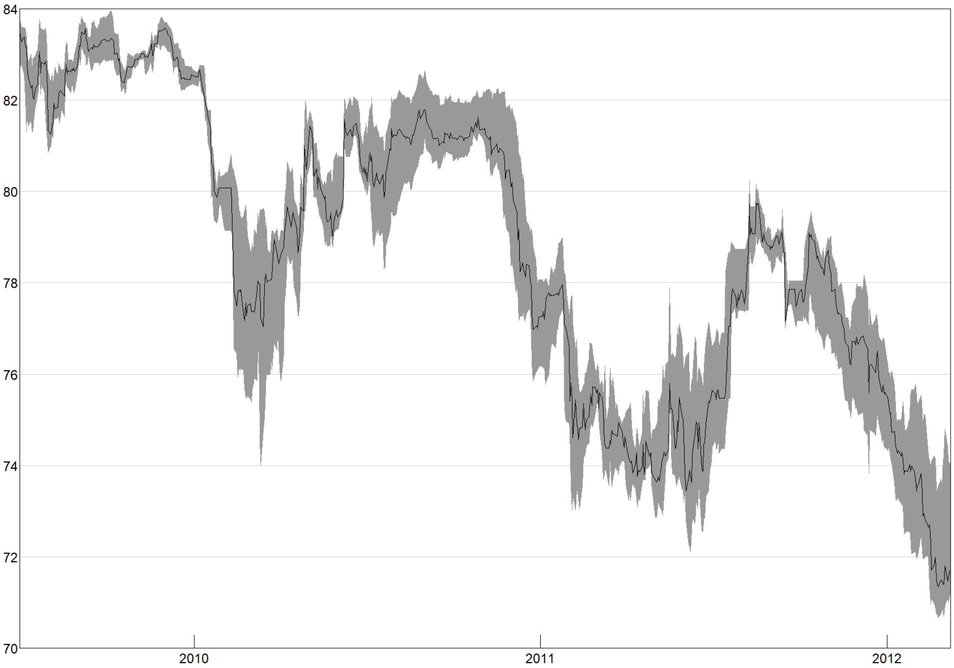
Note: This figure presents the line chart of nine countries' sovereign credit default swaps yields daily growth rates in post-crisis period which starts from 26 September 2013 to 10 March 2020. The growth rates are measured as percentage (%).
Source: Thomson Reuters Datastream and self-calculation.

Figure C3: Sovereign Credit Default Swaps Growth Rate in Pandemic Periods



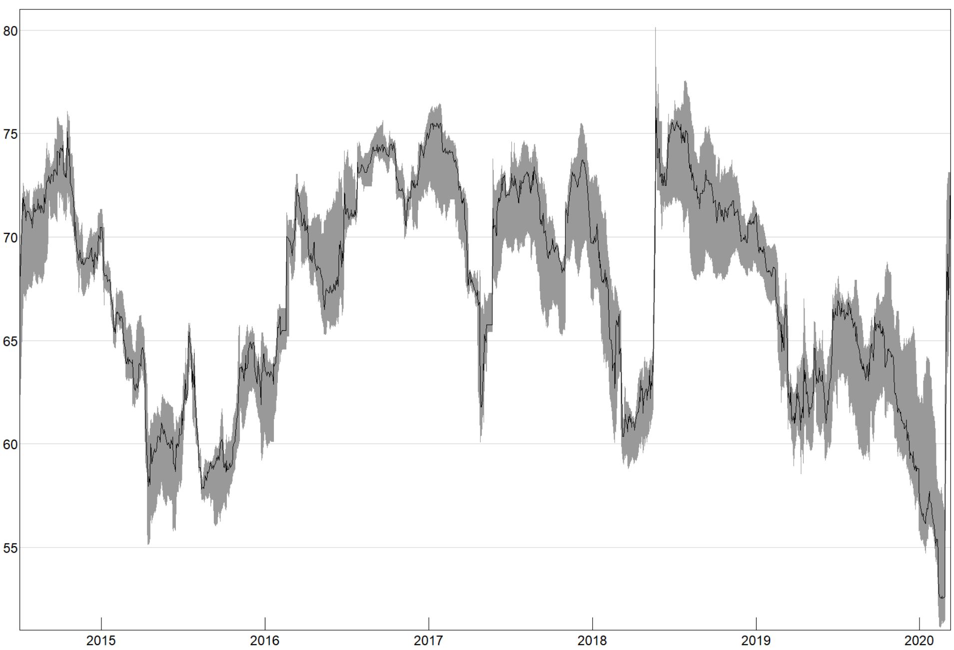
Note: This figure presents the line chart of nine countries' sovereign credit default swaps yields daily growth rates in pandemic period starts from 11 March 2020 to 30 January 2023. The growth rates are measured as percentage (%).
Source: Thomson Reuters Datastream and self-calculation.

Figure C4: Sensitivity of the index to VAR lag structure (Max, Min and Median values of the index for VAR order of 2 through 6) - First Sub-period



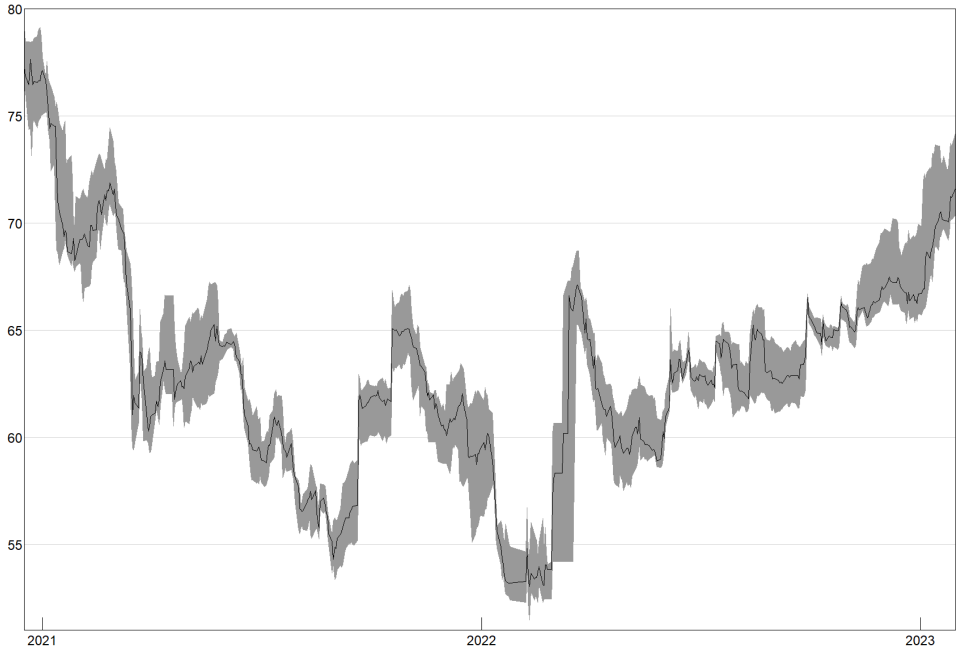
Note: The figure shows the spillover index for orders 2 through 6. The shadow part contains Min to Max values of the index. The balck line inside shadow indicates the median values. The first sub-period starts from 15 September 2008 to 8 March 2012.
Source: RStudio.

Figure C5: Sensitivity of the index to VAR lag structure (Max, Min and Median values of the index for VAR order of 2 through 6) - Second Sub-period



Note: The figure shows the spillover index for orders 2 through 6. The shadow part contains Min to Max values of the index. The balck line inside shadow indicates the median values. The second sub-period include data from 26 September 2013 to 10 March 2020.
Source: RStudio.

Figure C6: Sensitivity of the index to VAR lag structure (Max, Min and Median values of the index for VAR order of 2 through 6) - Third Sub-period



Note: The figure shows the spillover index for orders 2 through 6. The shadow part contains Min to Max values of the index. The balck line inside shadow indicates the median values. The third period starts from 11 March 2020 to 30 January 2023.
Source: RStudio.

Chapter 5

CONCLUDING REMARKS

This thesis critically investigated the determinants of sovereign risk levels among European periphery countries, analyzing them from various perspectives across different periods. Chapter 2 focused on the government bond spreads, which represent the differentials between the bond yields of each country and German bonds. This analysis was conducted through an empirical approach using the dynamic panel model (De Santis, 2012). It assessed potential determinants of sovereign risks, such as credit ratings, economic fundamentals, and monetary policies. With sovereign bond spreads in the secondary market which vary each second, and GDP data released quarterly, the chapter employed a quarterly data framework to structure models of bond spreads and economic fundamentals. To offset the potential deficiencies of using low-frequency data, which lacks crucial information on dependent variables, Chapter 3 incorporated a key macro-fundamental variable—industrial production, announced monthly. This allowed for a broader sample size and facilitated the analysis of interrelationships between sovereign CDS spread shocks and other determinants at a higher, monthly frequency. Further, Chapter 3 advanced the discourse by analyzing the impacts of monetary policy on sovereign CDS spreads, applying the Vector Autoregressive model based on an assumption of endogeneity of the included variables and two types of Granger causality approaches. Chapter 4 supplemented this analysis with a focus on the spillover effects within the Eurozone, adopting Diebold and Yilmaz's (2012) directional spillover approach employing data frequency for both core and periphery countries in Europe. The methodologies and results of all chapters are complementary and shown to be robust, significantly contributing to the discourse.

Specifically, Chapter 2 employed nine dynamic panel regressions to probe potential determinants of PIIGS countries' sovereign bond spreads. The results exposed the significant impact of the European Central Bank's interest rates on sovereign bond spreads compared to the M3. This revealed that the sentiment in the sovereign bond market is more sensitive to central bank interest rate adjustments than to variations in M3, which carries pertinent implications for bond investors' behaviour and central bank policy formulation. Intriguingly, post-crisis interest rate adjustments appeared beneficial for all five countries' sovereign risk reduction, with the exception of Ireland in the pre-crisis period. The GDP growth rate variable held significance primarily in the pre-crisis model, with Italy's fiscal and economic conditions becoming more crucial post-crisis. Furthermore, this study highlighted that the VSTOXX index, rather than the commonly used VIX, was a superior predictor of bond spreads in the Eurozone market post-crisis, contributing significantly to understanding investor behavior in systemic risk contexts.

The insights drawn from Chapter 2 proposed a comprehensive perspective for market participants, facilitating the assessment of investment risk through the lens of credit ratings, GDP, and overnight deposit rates offered by banks, thus optimizing return potential. In contrast with M3, both investment funds and individual investors should dedicate more focus to the repercussions of central bank overnight interest rate modifications when contemplating fluctuations in sovereign bond yields. Similarly, when deliberating interest rate adjustments, central banks should account for their effects on national sovereign bond markets, particularly during crises that primarily revolve around sovereign credit issues. After the European debt crisis, it became of paramount importance for sovereign bond investors to remain vigilant towards shifts in monetary policy and

European stock market sentiment rather than the economic fundamentals of Eurozone nations. Within the purview of investment strategies, alterations in credit ratings could serve as an indicator for bond spreads, albeit a higher credit rating did not inherently denote a more stable sovereign bond market, as evidenced by the cases of Spain and Ireland. When conducting analyses of specific countries, greater weight should be accorded to the influences of policy factors and market investment sentiment.

Chapter 3 undertook an innovative application of linear and non-linear Granger causality tests based on the VARNN model to the CDS market. Contrary to prior literature, our model incorporated the European stock market index and included macroeconomic variable shocks in lieu of the traditionally used American stock market index. Our findings underscored the significant influence of sovereign markets on stock market sentiment. In Chapter 2, we encapsulated the notable interconnection between sovereign credit and stock market sentiment, drawing upon data from sovereign bond spreads. Chapter 3 not only reinforced the established relationship between sovereign credit and equity markets, but also elaborated on the influence that sovereign markets exert on stock market sentiment, rather than vice versa. Moreover, our research unveiled the significant contribution of the ECB interest rate shocks to the positive response of sovereign CDS shocks across all five peripheral nations during the crisis period. Echoing insights from Chapter 2, we reaffirmed the generally significant causality between interest rates and sovereign credit. Therefore, we could deduce that the ECB's monetary easing considerably mitigated sovereign credit risk in Europe's peripheral nations amid the European debt crisis, which commenced in 2010.

The findings from Chapter 3 served as a valuable guide for those investing in sovereign CDS. Specifically, during times of crisis, they should pay more attention to policy trends. Historical evidence suggested that the implementation of quantitative easing monetary policies has proven effective in diminishing the sovereign credit risk associated with various nations. Concurrently, investment funds and individuals participating in the European stock market should also focus on the sovereign CDS market - the fluctuations in sovereign CDS across various peripheral countries in the Eurozone significantly influenced the investment sentiment in the European equity market. Moreover, our research reemphasized the importance of the sovereign CDS market. It is incumbent on policymakers to craft sound policies aimed at stabilizing market sentiment, including that of the stock market, by referring to the response of sovereign CDS in various countries to interest rate shocks.

To further comprehend the determinants of Eurozone periphery countries' sovereign risks, Chapter 4 focused on the spillover effect of changes in sovereign CDS in the euro area, ranging from the GFC and the European sovereign debt crisis up to the end of the COVID-19 pandemic. Our research filled the gap in understanding spillover effects in sovereign credit markets during the post-crisis period and throughout the pandemic. Countries with significantly changing spillover effects over time were identified, such as France, Greece, and Italy, with Spain and Portugal emerging as the primary transmitters of spillover effects in the long run. Moreover, our findings demonstrated that the contagion effect of sovereign CDS among Eurozone countries is more pronounced during times of crisis than in non-crisis periods. In the most recent past, during the COVID-19 pandemic, the spillover effects amongst these nations were less severe compared to the Eurozone debt crisis era.

Spillover effects are generally ubiquitous across most financial markets, and our research on contagion effects within the sovereign CDS market offered valuable insights for market participants. Firstly, as the intensity of spillover effects fluctuated across different time periods, investors should meticulously evaluate the current economic conditions in their decision-making process to accurately analyse the potential varying degrees of sovereign CDS contagion risk across different markets. Given the varied levels of risk spillover across countries in different periods, our research suggested that investment strategies should primarily consider Spain and Portugal as key risk spillover nations in order to gauge the potential contagion risk impacts on other Eurozone countries. Similarly, when formulating policies, the dynamic correlations between both major risk spillover transmitters and risk receivers should be taken into account. If policy implementation effectively reduces the sovereign credit risk of major risk spillover transmitter nations, then the sovereign credit of the main risk receiver countries will also be effectively alleviated by reducing the spillover risk.

This thesis advanced our understanding of the determinants and spillover effects of sovereign credit risk across different periods and holds valuable insights for financial stakeholders, including international investors, supervisory organizations, and portfolio risk managers. The findings in Chapter 2 provided a comprehensive overview for investors, enabling them to measure investment risk from the perspective of credit ratings, GDP, and bank overnight deposit rates. The results of Chapter 3 offered insights not only for general investors but also for policymakers. The divergent effects on the stock market, sovereign CDS, and industrial production from ECB's interest rate and aggregate monetary growth across countries and periods presented a challenge for authorities in balancing multinational adverse effects from monetary policy adjustments. Moreover, the findings from Chapter 4 highlighted the temporal dynamics of spillover risks, suggesting that Spain and Portugal, as major transmitters, are potentially less exposed to spillover effects from other countries. To assess a country's risk level, the dynamic nature of sovereign CDS spreads' contagion effects could provide a crucial reference for the European Central Bank in formulating policy decisions.

In conclusion, this thesis not only enriched the academic literature on the subject but also provided practical insights for policymakers and investors navigating the European sovereign credit market. The depth and scope of this work made a substantial contribution to the discourse on financial crises, creating a foundation for further scholarly inquiry while offering pragmatic strategies for investment and policy decisions.

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